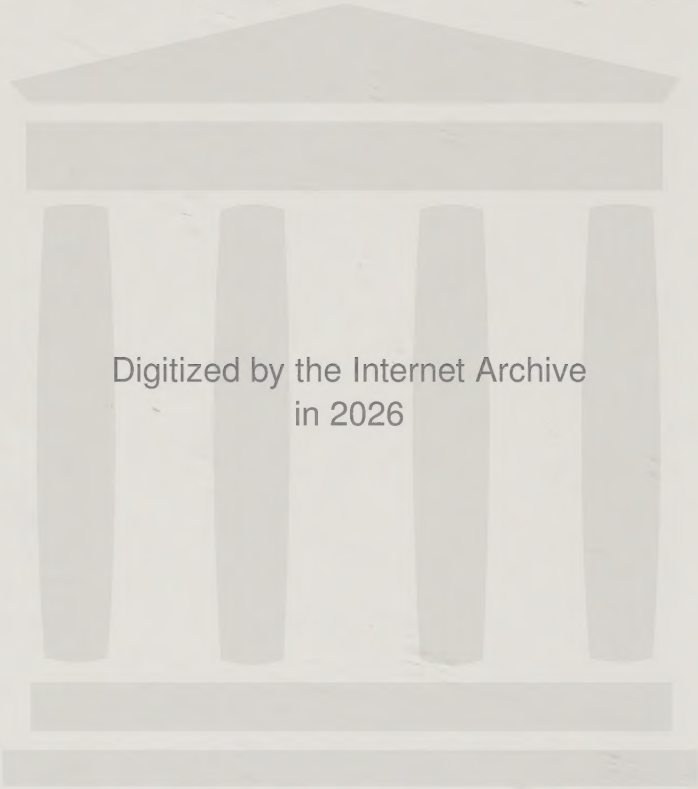
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Zella A. Perkins

DISINFECTION
AND
THE PRESERVATION OF FOOD

DISINFECTION

AND THE

PRESERVATION OF FOOD

TOGETHER WITH AN ACCOUNT OF THE CHEMICAL SUBSTANCES USED AS ANTISEPTICS AND PRESERVATIVES.

BY

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PREFACE.

No recent attempt has been made to summarise and review the very voluminous literature on the subject of Disinfection which is scattered through our own and foreign Scientific and Medical publications, and, notwithstanding the rapid development of Sanitary Science in this country, there does not exist at the present time, in the English language, any book which deals exclusively with the composition of Disinfectants.

The present volume may, therefore, supply a want which has been felt, not only by the chemist and bacteriologist, but also by all those who, like medical officers and borough surveyors, are concerned with the practical work of Disinfection.

Owing to the attention which has been given to bacteriological science during the last ten years, the methods of Disinfection are now being reviewed under the more exact conditions which this knowledge has rendered possible. The time is not far distant when the importance of thorough disinfection of all suspected areas will be fully realised by local authorities, and when all such work will be entrusted to specially qualified men, instead of being regarded as the subsidiary duty of the inspector of nuisances. The Sanitary Institute of Great Britain has for some years insisted that the duties of a Sanitary Inspector are such as to necessitate a considerable amount of practical experience and scientific knowledge. If, as at present, the proper carrying out of the work of Disinfection forms part of their duties, the responsibility of such men is considerably augmented.

It has become customary in many districts for the public analyst to advise the sanitary committee on the chemical composition of new disinfectants, and, although this practice should without doubt be generally adopted, it must not be forgotten that a continuous control over the strength and bactericidal activity must be maintained after any particular disinfectant has been finally selected.

The laudable attempts of the medical officers of health in some districts to stamp out sporadic outbreaks of infectious disease as soon as they are notified to them, are to a considerable extent nullified by the slackness which obtains in neighbouring areas, where a lavish display of untested disinfectant powders in the street gullies, or the use of a strongly-smelling or high-coloured fluid of unknown composition, is relied upon to satisfy the public demand for hygienic conditions of life.

The following pages may help in discriminating between useful disinfection and the futile attempts which give a false sense of security to many localities in the time of danger.

I am indebted to Mr. H. B. Ransom, A.M.Inst.C.E., for the principal portion of the chapter on Disinfection by heat, and his practical acquaintance with the engineering details of different forms of disinfecting plant has enabled me to give this section much greater value than it otherwise would have possessed. For several suggestions and the account of methods for the bacteriological examination of disinfectants, I have to thank my former colleague, Dr. C. Slater, of St. George's Hospital; and my thanks are also due to Dr. Louis Parkes, the Medical Officer of Health for Chelsea, for advice and for his kindness in reading the proof sheets.

SAMUEL RIDEAL.

Westminster,
June, 1895.

PREFACE TO THE SECOND EDITION.

In this New Edition I have endeavoured, in the form of appendices, to incorporate the progress made during the last two years. Several corrections have been made in the body of the volume, and the index and bibliography have been enlarged. A considerable portion of the chapter on halogen compounds has been re-written.

SAMUEL RIDEAL.

Westminster,
July, 1898.

PREFACE TO THE THIRD EDITION.

THIS Edition has been entirely reprinted, and I have altered and revised the book, with such additions as will bring the subject up to the present time. This has involved some excisions and condensations of earlier matter, but all the more important historical portions have been retained. Since the publication of the last edition I have had the opportunity of much experience on special points, and have undertaken researches which have yielded interesting results. The substance of these will be found in the text.

I trust that the enlargement of the section on food preservation will make it a manual of practical value to those engaged in many of our largest trades and industries. Notwithstanding a general consensus of opinion against the use of preservatives a few years ago, it would seem impossible, under modern conditions of life, to do without some methods of keeping perishable articles of food without incurring a very large loss, and it cannot be denied that, with proper safe-guards, in some instances even chemical treatment may be desirable.

SAMUEL RIDEAL.

28 Victoria Street,
Westminster,
October, 1903.

TABLE OF CONTENTS.

			PAGE
CHAPTER	I.	INTRODUCTORY	1
,,	II.	MECHANICAL DISINFECTION	9
,,	III.	STERILIZATION BY HEAT	27
,,	IV.	CHEMICAL DISINFECTANTS: THE NON-METALLIC ELEMENTS AND THEIR DERIVATIVES ...	77
,,	V.	THE NON-METALLIC ELEMENTS AND THEIR DERIVATIVES (*continued*)	110
,,	VI.	METALLIC SALTS	147
,,	VII.	METALLIC SALTS (*continued*)	173
,,	VIII.	ORGANIC SUBSTANCES	198
,,	IX.	ORGANIC SUBSTANCES (*continued*)	243
,,	X.	ORGANIC SUBSTANCES (*continued*)	264
,,	XI.	COMPOUNDS RELATED TO THE ALCOHOLS ..	294
,,	XII.	PRACTICAL METHODS	330
,,	XIII.	PERSONAL AND INTERNAL DISINFECTION ...	385
,,	XIV.	PRESERVATION OF FOOD	408
,,	XV.	LEGAL STATUTES AND REGULATIONS	436
,,	XVI.	METHODS OF ANALYSIS	451
		INDEX	485

DISINFECTION AND DISINFECTANTS.

CHAPTER I.

INTRODUCTORY.

Definition of Terms—Primitive Methods of Disinfecting—Bacteriology—The Methods of dealing with Bacteria by Exclusion, Removal, and Destruction.

Definition of Terms.—The words "disinfectant" and "disinfection" have in recent years been used in such a variety of ways, and with such wide application, that much confusion has arisen as to the exact meaning of these terms.

Before the germ theory was universally accepted, the term "disinfection" was used to include the destruction of infectious matter and the removal of any noxious odours to which such matter gives rise. It was applied to the action of any substance which served as a mask for noxious odours, and many strong smelling substances have probably become popular, as disinfectants, solely from this cause. After the germ theory had offered a plausible explanation of the origin of disease, it became possible to define a disinfectant as a germicide. Disinfection then ceased to mean simply "purification," but acquired the special meaning of "sterilization." A true disinfectant, therefore, must not only mask the smell, but must destroy or kill the germs which give rise to it. Many poisons have the property of killing germs as well as acting upon the higher forms of life, and could, therefore, be used as universal destroyers of life; but, in many cases when disinfection is resorted to, it is desirable to use some agent which will discriminate between useful life and infectious matter. Such an ideal *disinfectant* should, therefore, be a substance that will kill those germs which

act injuriously on the higher forms of life, without having any marked action upon such higher forms. A disinfectant must likewise be efficient in destroying the *spores* of pathogenic organisms, which, as a rule, are more resistant than the germs which form them. From this definition it will be seen that a disinfectant does much more than prevent decomposition, and does more than remove the noxious smells which often emanate from putrefying matter. A disinfectant really goes to the source of the trouble, and, by killing the organisms, prevents the spread of epidemic disease. An *antiseptic,* on the other hand, prevents animal or vegetable substances from undergoing decomposition, and a body is said to be *aseptic* when it is in a condition of sterility. A substance which has the property of absorbing the unpleasant odours which are emitted from matter undergoing decay is called a *deodorant,* and such substances must be carefully distinguished from true disinfectants. Most disinfectants are deodorants; but a deodorant, unless of a permanent character, is not an antiseptic, and is still less a disinfectant. It is true that in most cases a noxious smell accompanies decay, and, therefore, that any substance which permanently removes the smell must necessarily cause the cessation of decay; but in other cases in which there is no appreciable odour, a deodorant would not be required. Charcoal is an example of a body that will absorb any unpleasant smell which may arise from organic matter, but which does not kill the germ producing the decay. Although commonly called a disinfectant, it should be more properly classified among the deodorants.

The two branches of our subject have several essential differences. *Disinfection* is the destruction of pathogenic organisms, and agents may in many cases be used which are poisonous to human life. In the *Preservation of Food,* the object is to prevent change: the organisms need not be dangerous to life, and a simple retardation of their actions for a certain time is frequently sufficient. Antiseptics have here a province, but any agent used must be non-poisonous, and must not communicate an objectionable taste or odour. In a closely allied subject, the prevention of decay in timber and materials, and in some applications in surgery and personal hygiene, no such restrictions are required.

Primitive Methods of Disinfecting.—Man has an instinctive repugnance to all offensive exhalations, and from the earliest time has sought to mask their presence by the aid of aromatic substances. The use of perfumes is probably a relic of the effort of primitive man to counteract unpleasant odours. Many religious ceremonies, such as the burning of incense, have also the same origin, and embalming, as practised by the Egyptians, is a good example of successful attempts to arrest putrefaction in very early ages. Sulphur has been employed from the earliest times, and Homer describes its use in religious ceremonies. In the time of Hippocrates, sulphur was regarded as an antidote against the plague. Ovid makes mention of the fact that the shepherds of his era used sulphur for bleaching fleeces and for purifying their wool from contagious diseases. During the plague of Athens, Acron, according to Plutarch, stayed the spread of the epidemic by lighting fires in the middle of the public places and in the streets where deaths had occurred; and the lighting of fires during times of plague has been customary until quite recent times.

It seems, however, to have been believed in 1665 that the street fires at the period when the Great Plague of London was at its height rather intensified the evil than diminished it: if this be so, it was probably due to their causing a concourse of people and so helping to disseminate infection. The fires would be useful for ready cremation of infected articles, but the proportion of the air that would be sterilized would of course be trifling.

The Mosaic law, with all its minute instructions as to the purification of the people and their belongings, shows the same combination of religious ceremonial and sanitary precautions; this law, undoubtedly, contributed to the permanence of the Jewish race during its early history. The Indian who, instead of embalming or burying his dead friend, hangs the body under a tree exposed to the air, makes use of the property of desiccation, which, as is well known, is very efficient in arresting decay, and is the basis of many modern patents. Earth is a very powerful deodorant and in certain cases seems to be antiseptic; the gases given off by decaying bodies are absorbed, and thus the burying of a body under proper conditions may be regarded as an

efficient means of disinfection. The use of fire for cremating bodies undergoing decay or likely to cause a nuisance is, of course, an illustration of the employment of heat for the destruction of micro-organisms.

Disinfection in the Middle Ages.—During the long period of the Middle Ages, the alchemists did little to advance our knowledge of this subject; they collected a few facts, and described, with more or less accuracy, the properties of some of the more important chemical compounds; but one may search in vain for a correct account of any example of preventive medicine. Notwithstanding the ravages of the cholera, the plague, and other epidemics, as well as the frequency of leprosy, the idea of contagion was only imperfectly understood, and the people generally were far less cleanly in their habits than the Jews, for example, or heathen nations who, as we have already mentioned, mingled primitive sanitary precautions with their religious services. Perhaps one of the earliest papers of any importance which we have is a *Mémoire sur les substances septiques et antiseptiques*, written by Pringle in the middle of the eighteenth century. In this *Mémoire* some forty-eight experiments are described, in which the author took pieces of fresh meat and placed them in contact with various amounts of substances which he believed to have an antiseptic action. Among the substances tried we find common salt, sal ammoniac, acetates of ammonia and potash, nitre, borax, alum, camphor, aloes, and succinic acid. These experiments, which were conducted in a very systematic manner, are even now not without some value. By taking as a standard the antiseptic action of 60 grains of salt on 2 grains of meat in 2 ounces of water, he was able to show that the other bodies enumerated above had a greater antiseptic power than this standard, and thus succeeded in arriving at their relative antiseptic value.

Bacteriology.—Even the pioneers of modern chemistry at the beginning of the present century, did little towards promoting our knowledge of disinfectants, and it was not until the biologist showed that decay was due to the action of living organisms which float in the air, that fresh attention was directed to the subject. Francesco Redi, by protecting meat from flies with wire gauze, showed that the

maggots which infest decaying flesh were produced from the eggs of the flies. Subsequently the formation of moulds on the surface of jams, or other organic substances, was similarly shown to be determined by micro-organisms floating in the air. It was further noticed that infectious diseases spread more rapidly in damp warm weather when there is very little wind, and that filtration of the air through cotton wool was effectual, not only in removing the dust, but also in preventing the ingress of micro-organisms.

The gradual accumulation of such facts as these by the biologists led the chemists to realise that the removal of the odour was not, after all, the only work required to be done, and the use of fumigations with nitrous acid, hydrochloric acid, and chlorine and other pungent bodies, which had been recommended, fell gradually into disfavour.

Pasteur's work, together with the general development of the modern science of bacteriology, has given to chemists a means of ascertaining the relative value of the various chemical substances discovered from time to time. It was to Pasteur's careful investigations that the close analogy which exists between fermentation and putrefaction was established. Pasteur himself defined putrefaction as "fermentation without oxygen," and showed that all decay was due to the action of organisms, the name *Bacterium termo* being then applied to the group which begins eremacausis.

In recent years the life-history of known species has been carefully studied, and the chemical changes which are produced when they live in media of known compositions have been followed. Thus organisms have been allowed to grow in solutions of calcium formate and calcium acetate, both of which substances have a definite chemical constitution. The bacteria decompose these salts, evolving carbonic acid gas mixed with hydrogen in the former solution, and carbonic acid mixed with marsh gas in the latter. Lactic acid and its salts, butyric acid and its compounds, as well as other chemical substances of known constitution, have also been examined bacteriologically. From studies such as these it is clearly established that, just in the same way as the yeast when it converts sugar into alcohol is killed by the alcohol it produces, so these other micro-organisms secrete chemical compounds which are inimical to their own life. In the

decomposition of animal matter containing nitrogen, compounds which are soluble in weak alkaline solutions, and known as alkali albumens, are first produced, and these subsequently change into albumoses and peptones, to be again broken down into tyrosine, indol, and other compounds. These latter have strong antiseptic properties, and illustrate the fact already alluded to—viz., that the products of decomposition are, in the majority of cases, themselves inimical to the bacteria which give rise to them.

The Methods of dealing with Bacteria.—The ideal of disinfection is to stamp out the pathogenic bacteria, just as weeds are extirpated from a garden. This can never be done until their hotbeds, the filthy slums of cities and the neglected country villages, are cleansed and supplied with plenty of good water, and, in the cities, with air and, above all, light. Every dirty court or alley is an admirable culture-medium in which disease organisms may multiply; these issuing in a variety of ways, as by clothes, food, and even sometimes by the atmosphere, may unexpectedly decimate the so-called better neighbourhoods. There is no reason why infectious disease of all kinds should not be entirely abolished; but it can only be done when the entire population is supplied with knowledge, and placed under conditions in which health is possible. At present it is indispensable that measures of precaution should be taken continually and habitually to prevent any outbreak rather than, as too often is the case, only spasmodically when a plague like cholera threatens. The success of improved sanitation in rendering obsolete in modern Europe such plagues as carried off millions at intervals in the Middle Ages, shows that the abolition of infectious disease is possible, but we have still among us "that sad disgrace, our customary (and preventable) autumnal epidemic of scarlatina." This would certainly yield to a vigorous and systematic insistence upon isolation and application of disinfectants. With reference to the first precaution, more and better accommodation will have to be provided. As to the second, one great reason of the want of progress has been the fact, that many of the modes of disinfection, even those prescribed by high authorities, are absolutely inefficient and useless. We must get rid, to begin with, of the idea that the creation of a rival

smell is any criterion of safety; we must cease to be misled by laudatory advertisements, and antiquated opinions founded on inaccurate experiments before bacteriology became a science, and we must not grudge the expense of a sufficient quantity and a proper application of the disinfectants that have been proved scientifically to really effect their purpose. The problem then resolves itself into a struggle for existence between man and inimical micro-organisms which are known to have great vitality, powers of endurance, and facilities for penetration, accompanied by a stupendous fecundity. The means at present at our disposal for dealing with this problem can be classed under three heads:—

1. Exclusion.—The rough methods of quarantine and sanitary cordons have not proved a success, since the ways of ingress are so many and wide, and the intolerable oppressiveness of these regulations leads certainly to their frequent evasion. The English methods of inspection, and temporary closure of certain routes, have proved much more effectual. It is satisfactory, for instance, to hear of the precautions which are being taken by the Local Government Board with the object of lessening the chance of plague being imported into this country. Cholera killed many people, but it did an immense service to England by forcing us to protect our water supplies. The last, or personal, line of defence lies in the care and precautions taken by the individual. Most of these are indicated in Chapter XIII., "On Personal and Internal Disinfection." Cleanliness, fresh air, light, and good water are the chief.

In recent years it has also been shown that many, if not all, zymotic diseases may be excluded from the person by the introduction of special *toxines* into the individual, a process which renders him immune from the attacks of the organisms that produce the disease. These toxines are produced by the pathogenic organisms themselves, and, as already mentioned, are usually inimical to the growth of the organism, and may be regarded as their natural disinfectants. In view of these facts, Pasteur and his successors have cultivated the pathogenic organisms in broth and other media, and after sterilization have injected the liquid products as prophylactics against various diseases. The virus

can also be attenuated by passing it through different animals, or by special methods of taming, until, whilst still producing the toxines, it can be introduced into man without producing any dangerous symptoms, and thus can render him immune from fresh attacks, or place him in a position to develop the natural disinfectant sufficiently rapidly to kill off the pathogenic organisms, even after they have gained access to the blood. Dr. Roux, for example, at the Vienna Congress in 1894, reported a large number of cures of diphtheria by injecting a quantity of serum from the veins of a horse previously inoculated with Lœffler's diphtheria bacillus. Under the name of antitoxine, this diphtheria antidote is now a commercial article, and may be regarded as a special disinfectant for dealing with the organisms of this disease.

2. Removal.—Under this heading may be included the natural processes which obtain in a healthy individual, and artificial methods for improving his environment. It is now well established that the blood by its white corpuscles, as "phagocytes," or by its enzymes, has the power of assimilating and destroying bacteria and spores that find their way into it. If vigorous health be maintained, experience proves that a human being or animal may enjoy immunity for a time, even when in an infectious area. The limit to this protection may be reached when the micro-organisms overcome the phagocytes or other defensive substances in the blood. Many natural processes, external to the individual, such as the self-purification of rivers, aid the higher organisms in this combat. Man, by artificial methods of subsidence, mechanical precipitation by inert matters, filtration, and chemical precipitation, supplements these efforts of nature to purify the water supplies.

3. Destruction.—This is the office of real disinfectants, of which the physical agent heat is the most important. Next come the multitude of chemical disinfectants, many of which have been highly vaunted, but few of which are of actual value. A knowledge of the chemical constitution and relative position of these compounds throws considerable light on their mode of action; and recent progress in synthetical organic chemistry has been of great assistance in furnishing compounds of known purity and constitution, which have,

at the hands of the bacteriologist, been shown to possess antiseptic and disinfectant properties of ascertained value. The number of these compounds is constantly on the increase, but at present it is difficult to predict, except in some few special cases, in what direction the constitution of a compound influences its bactericidal behaviour. Pathogenic organisms have been proved to differ in their susceptibility to chemical agents, so that, for personal disinfection at any rate, some of the newer compounds may eventually be proved to be definite specifics.

CHAPTER II.

MECHANICAL DISINFECTION.

Insufficiency of Deodorisation—Physical Means—Light capable of killing Bacteria—Sunlight and ordinary Daylight—Conclusions—Substances comparatively Inert: Carbon—Animal Charcoal—Vegetable Charcoal—Disinfection Gratings—Use in Closets—Peat Charcoal—Coke—Soot—Coal-dust—Peat—Sawdust—Clay—Dried Earth—Spongy Iron—Infusorial Earth or Kieselguhr—Ashes and Cinders—Gypsum—Purification of River Water: Sand Filtration—Principles of its Action—Mechanical and Sterilizing Filters—Clark's Method—Gaillet and Huet's Process—Natural Purification—Cold and Desiccation: Resistance of Microbes to Drying—Survival in Soil.

Insufficiency of Deodorisation.—The simple removal of smell, or even the act of disguising it by a chemical or more powerful odour, is frequently looked upon as disinfection. Yet it is obvious that the removal of the injurious products of putrefaction, although it may be of temporary benefit, will not prevent the organisms from reproducing a further quantity. There are also a number of micro-organisms known in whose growth there is never any ill smell evolved, and no ammonia or sulphuretted hydrogen detected; but which, at the same time, form ptomaines, and are in other ways dangerous to health. Some of these, as pointed out by Klein, may evolve an aromatic smell and thus be tolerated.

In those cases in which it is advisable that large volumes and surfaces should be sterilized, it is not usually practicable to kill all the bacteria by chemical agents; therefore recourse must be had to their removal by physical means.

Light.

The action of light is one of the most important of these physical agencies for diminishing the number of microbes, and its recognition was foretold in the words of the late Sir David Brewster, who in his address delivered to the Royal Society of Edinburgh at the opening of the session of 1866-1867, said: "If the light of day contributes to the development of the human form, and lends its aid to art and nature in the prevention and cure of disease, it becomes a personal and national duty to construct our dwelling-houses, schools, workshops, factories, churches, villages, towns, and cities upon such principles, and in such styles of architecture as will allow the life-giving element to have the fullest and freest entrance, and to chase from every crypt, cell, and corner the elements of uncleanness and corruption which have a vested interest in darkness."

Downes and Blunt[1] first demonstrated the antagonistic action of light towards bacteria. Test tubes containing sterilized Pasteur solutions were exposed to intermittent sunlight and diffused daylight for periods varying from days to months, having been previously infected by minute quantities of liquids containing bacteria, or else exposed for a time to ordinary air. A similar set of tubes were covered completely with tin-foil to exclude light, other conditions being the same. They found that direct sunlight in some cases entirely prevented the development of the organisms, in others only retarded it, and that even diffused daylight had a distinctly deterrent effect. The blue and violet rays of the spectrum were much more active than the red and orange. They further showed that the influence on spores was not exerted in a vacuum, that the nutritive value of the culture liquids was not affected, and that the bacteria were much more resistant when immersed in water than when surrounded by any other medium. From these facts they attributed the destructive effect of light to the promotion of oxidation by the influence of the sun's rays—*i.e.*, to the so-called actinism of light. (See Chapter xiv. as to the influence of light on the rancidity of butter.)

A number of other investigators continued the research with pure cultivations of pathogenic and pigment-producing

[1] *Proc. Roy. Soc.*, Dec. 6th, 1877.

bacteria. Duclaux experimented with *Tyrothrix scaber* and micrococci, and demonstrated that the power of resistance to light varied with the species, the kind of nutrient medium and the intensity of the light. It was noticed that the sun's rays appeared to favour the development of several kinds of yeast and moulds, and that the action of light was increased by the presence of air.[1] Pansini[2] found that the destruction was rapid during the first period of exposure (360 colonies of *B. anthracis* being reduced in half an hour to 4), but afterwards proceeded much more slowly. The spores of anthrax in a dry state were more resistant to light than when moist; in the latter case an exposure of from thirty minutes to two hours was sufficient to destroy them. Engelmann showed that a few bacteria are not unfavourably influenced: *B. photo-metricum* only became motile when exposed to light. Koch says that sunlight, or even ordinary daylight, will kill tubercle bacilli in from a few minutes to five or seven days, according to the thickness of the stratum.[3] Janowski has also proved that four to ten hours' sunlight destroyed typhoid bacilli. After passing through a solution of potassium bichromate, so as to cut off the blue and violet portions of the spectrum, the rays had no effect.[4] He showed also that the effect of the light was not due to increase of temperature. Geister demonstrated that an electric light of 1,000 candle power at 1 metre distance was less effective than direct sunlight.[5] Marshall Ward[6] showed that the dried spores of anthrax were acted on by light in the absence of food materials, and that the light did not appreciably diminish the nutritive value of the agar-agar medium. Khmeleosky finds that both solar and electric light inhibit the growth of *Staphylococcus pyogenes aureus*, *Bacillus pyocyaneus*, *Streptococcus erysipelatis*, and *S. pyogenes*. Sunlight destroys their vitality in about six hours, and exposure to sunlight seems to mitigate their virulence when it does not destroy them. It also makes the media less

[1] Arloing and Gaillard, *Influence de la Lumière sur les Micro-org.*, Lyon, 1888; Uffelmann, *Hyg. Bedeut. des Sonnenlichtes*, 1889.

[2] *Rivista d'Igiene*, 1889.

[3] *Zeitschrift für Hygiene*, vol. x., p. 285.

[4] *Centralblatt f. Bakteriol.*, 1890, pp. 167, etc.

[5] *Ibid.*, 1892, vol. xi., p. 161.

[6] *Proc. Roy. Soc.*, 1893, p. 310.

favourable to their growth.[1] Percy Frankland and others have examined the action of light on the organisms in the Thames and other waters.[2] Buchner has also shown that in water, typhoid and other cultures are destroyed by exposure to bright sunlight for three hours. By immersing cultures to different depths in the Sternberger Lake at Munich, he has further demonstrated that the bactericidal action does not extend to a greater depth than three yards, and that hence in the self-purification of rivers the action from this cause is chiefly superficial. The conclusions of the various researches may be summarised to the following effect:—

1. Light has a deleterious action on bacteria in their vegetative, and, to a less extent, in their spore forms.

2. The action is not caused by the rise of temperature. The ultra-violet rays are the most powerful, and the infra-red the least, pointing to chemical action.

3. The effect is greatly increased by the presence of air and moisture, so much so that it is undoubtedly due to a process of oxidation, possibly brought about by the agency of ozone or peroxide of hydrogen, or both. This view is supported by experiments by Richardson,[3] in which it is shown that peroxide of hydrogen is formed in urine during insolation, and that the sterilizing action of light can be counteracted by the addition of substances—*e.g.*, peroxide of manganese—which destroy hydrogen peroxide.[4] Richardson shows that the insolation of water alone does not generate peroxide of hydrogen. Dr. Frankland thinks that in the case of dried bacteria, or those suspended in pure water, the destruction is occasioned by the peroxide formed within their cells.

4. The action is not generally due to any alteration of the medium by light. Dieudonné, however, showed that culture media were sometimes changed by the production of peroxide of hydrogen.

5. The result varies according to the duration of the exposure, the intensity of the light, and the nature of the organism. Anthrax spores grown at 38° C. are much more

[1] *Brit. Med. Journ.*, 1894, p. 72.
[2] *Ibid.*, 1893, p. 20.
[3] *Proc. Chem. Soc.*, 1893, p. 121.
[4] P. Frankland, *Micro-organisms in Water*, 1894, p. 389.

easily killed by light than those obtained from the same source at 18° to 20° C.

6. There is no evidence that the virulence of anthrax undergoes any permanent attenuation through exposure to light.

7. Anthrax spores are less rapidly destroyed in distilled or potable waters than in culture media, or in an isolated condition. Their endurance is particularly long-continued in distilled water in absence of air, resistance to upwards of 110 hours' exposure having been observed by Momont.[1] The addition of a halogen salt, such as sodium chloride, materially increases the rapidity of destruction, while an oxy-salt, like sodium sulphate, has little or no influence.

8. The effect is much diminished by the rays passing through deep layers of water.

9. Whilst every opportunity should be afforded for insolation in the construction of water works, undue reliance must not be placed on this any more than on any other particular bactericidal agency (*Percy Frankland*).

Professor Esmarch has endeavoured to make use of sunlight as a practical disinfectant for skins and furs which cannot be sterilized in a steam disinfector. He finds, however, that, as might be expected, the light has only a surface action, especially on dark materials, and that it is, therefore, valueless when micro-organisms are likely to be present in the deeper parts.

In 1898 a process was submitted to the Boston (U.S.) Institute of Technology, for sterilizing meat by subjecting it for a number of hours to the actinic rays of an electric light, while simultaneously passing over it a current of air at 46° to 66° C. The product was afterwards powdered, when it had lost about 70 per cent. of its weight. Also see English patent 26,754 of 1897.

C. Roth asserted (*Z. angew. Chem.*, 1900, 633) that the phosphorescent light from sulphides of calcium, strontium or barium which had been insolated, destroyed different pathogenic organisms in a few hours, and proposed tubes containing them for surgical use in cavities of the body.

Röntgen and Radium Rays.—From the inhibiting and often destructive effect of light on bacteria it was anticipated

[1] *Ann. de l'Inst. Pasteur*, 1892, vol. vi., p. 21.

that the X-rays, on account of their peculiar physiological effect, would be specially active. Holtzknecht, however, reported in the Vienna *Klin. Rundschau,* in 1902, that he had exposed various bacteria to the strongest rays at a focal length of 15 centimetres for an hour, with a result of only temporarily hindering their growth. For the treatment of lupus the X-rays are less effectual than a powerful arc light. With the latter it has been proved that the activity lies in the blue, violet and ultra-violet rays, rather less than half the spectrum of the ordinary arc, therefore the practice has been to cut off the heat rays by a trough of copper sulphate solution. Iron electrodes give a greater proportion of chemical rays, and a lamp called the "Dermo" has been invented which develops the arc between hollow, water-cooled iron cylinders.

In June, 1903, Mr. Henry Crookes exhibited at the Royal Society, examples of the effects produced by exposing various cultures of bacteria to the action of 10 milligrammes of radium bromide, through a mica screen, at 2·5 centimetres distance, for 16 to 24 hours. The species tried were *B. liquefaciens, coli communis,* and *prodigiosus.* In every case a bare space, free from bacterial growth, was formed on the plate immediately opposite to the radium. The experiments are being continued to discover the minimum time and distance required for the bactericidal action.[1]

Mechanical Purification of Gases and Liquids.

Many almost inert substances have been used (1) for the removal of bacteria by mechanical straining or precipitation, (2) for the absorption of noxious emanations.

Carbon.—*Animal charcoal,* or bone-black, more particularly absorbs substances in solution. When thrown into sewage, especially with clay and other heavy powders, it carries down with it almost the whole of the suspended matters into the sludge, and also removes sulphuretted hydrogen, ammonia, the ptomaines, and the greater part of the other organic compounds, so as to leave the supernatant liquid nearly colourless and clear. If it

[1] Drs. Pfeiffer and Friedberger at Königsberg University since announce that exposure to 25 mgm. of radium bromide killed the organisms of cholera in 16, typhoid in 48, and anthrax in 72 hours.

could be used in sufficient quantity it would be one of the best of purifiers. It also effects a slow oxidation of the matters contained in the deposit, by means of oxygen which most forms of carbon absorb from the air. Unfortunately, it is an expensive material, as bones are in great demand for manure. A large number of processes, many patented, have endeavoured to recover the phosphate by using the sludge as a fertiliser, but they have all, so far, met with little commercial success.

Vegetable charcoal has a still greater power of condensing gases within its pores. One volume of wood charcoal will absorb the following volumes of different gases:—Ammonia 90, sulphurous acid 65, sulphuretted hydrogen 55, carbon dioxide 35, carbon monoxide 9·42, oxygen 9·25. Those gases and organic vapours which are capable of oxidation, and possibly bacteria, are destroyed when they come in intimate contact, within the pores of the charcoal, with the oxygen derived from the air. The charcoal should be freshly prepared, or should be reheated to a temperature short of ignition, as it rapidly loses in power. By charring again in closed vessels, it can be re-vivified many times. Charcoal derived from different woods has slightly varying powers of absorption; as a general rule, the more porous it is the greater the activity. Vegetable charcoal has less action on liquids than animal, and being lighter than water floats on the surface. Letheby, Stenhouse, and others proposed the use of gratings containing wood charcoal as ventilators for buildings and sewers: they did not, however, prove a success, as they soon become exhausted. If the dead body of an animal be buried in wood charcoal it decays without putrefactive odour, except that ammonia is evolved. Wood charcoal removes the odour of any decaying matter, and has been largely employed to restore tainted meat, by placing it in the water used for boiling, but although the taint is removed, the food is not thereby rendered wholesome. It may, however, be usefully employed when only a slight change has occurred.

Revill[1] long ago showed that charcoal is not, in a true sense, an antiseptic, since it rather hastens the decomposition of putrescible matters, although, by absorbing the

[1] *Archives génér. de Méd.*, 1863.

products, it renders the process inodorous—*i.e.*, it is simply a deodorant. Still it has considerable value for cesspools, water-closets, and dead bodies, when a removal is necessary. Goddard & Co. in 1887 patented an automatic purifying closet in which a mixture of animal and wood-charcoal, under the name of "Sanitary Carbon," was added mechanically to the excreta at each discharge. It was said to effectually deodorise the mass, and to produce a manure of some value. On shutting down the lid a sufficient quantity of the carbon is scattered over the excreta in the pan beneath, at a cost for each time of using of one-eighth of a penny.[1] In all these methods of using carbon it is found that, as the ammonia is rather rapidly evolved on exposure to air, the substance soon becomes almost devoid of nitrogen, and has practically no value as a manure.

Peat-charcoal is very light and absorbent. Its application has not been a success owing to its friability. Powdered coke, being denser, possesses much less power, yet it has been proposed in many patents for purifying sewage, either alone, or as an adjunct to other agents. As an instance, Kingzett in 1887 patented the use of a mixture of powdered coke and dry clay as a sewage precipitant. He states that the deposit can be readily pressed.

Coke alone has only a mechanical action.

Soot contains empyreumatic and bituminous matters in small quantity, and has therefore antiseptic properties due to these ingredients, but its power, though rather lasting, is not very great. It is moderately absorbent. In horticulture it is much used as an insecticide. Sprinkled about sewers and drains it removes the odour to a certain extent.

Coal-dust, being scarcely porous, is almost inert. Natural bitumens have long been used for embalming, but a great part of their effect is due to the mechanical exclusion of organisms. M. de Mily has recently carried out a number of experiments on the use of bitumens mixed with chopped rags (100 kilos. of rags to 10 of bitumen for 600 vines), to prevent the attacks of *Phylloxera* and other pests on ground that could not be treated with sulphur. The bituminous earth from Rhodes, which was mentioned by Strabo in 60

[1] *Lancet,* 1887, p. 886.

B.C., has also been recently used for this purpose. The results seem to have been satisfactory.

Peat itself when dried is of value for absorbing moisture and, with it, noxious emanations. 1 lb. of it (containing 25 per cent. of water) can take up seven and a-half times its weight. 100 lbs. of powdered peat will absorb 1,438 litres of ammonia. Several patents have been taken out for incorporating it with disinfectants, for which purpose it seems at first to be admirably suited for use in stables, etc. Ernst[1] proposes that peat or moss should be mixed with $2\frac{1}{2}$ per cent. of iron sulphate or phenol, and used for litter, privies, etc.[2] The odour of stables in which peat moss is employed is less than those in which straw is used as litter; on the other hand, powdered peat is now somewhat extensively used for dry closets, and has the advantage over earth of absorbing the urine. Schröder has also shown that it has a true disinfectant action on *Spirillum choleræ Asiaticæ*, although other pathogenic organisms are more resistant. Drs. Fränkel and Klipskin[3] have investigated the subject more minutely, and have established the fact that the organism of cholera when mixed with peat-dust is destroyed in about three hours, whilst under ordinary circumstances it may remain alive for fourteen days, unless the urine be acid. Dempster[4] has shown that it cannot survive in peaty soil. The addition of super-phosphate augments the disinfecting action of the peat, whilst kainite has little influence. These authors, therefore, strongly recommend the use of peat for isolated dry closets.[5]

SAWDUST, especially the varieties derived from pine wood, is widely used, on account of the resinous and aromatic compounds it contains, which seem to ozonise the air to some extent, and also give off an agreeable odour. It is not a good vehicle for disinfectants, as it is not very absorbent, but is often employed in country districts where there is no water supply for retaining urine in urinals.

CLAY, blast furnace slag, shale, and dried earth are all used for special purposes.

[1] Patent No. 2,581, 1882.
[2] Westknight and Gall, Patent No. 11,011, 1886.
[3] *Zeitsch. f. Hygiene*, 1893, p. 333.
[4] *Brit. Med. Journ.*, May 26th, 1894.
[5] See *Journ. Soc. Chem. Ind.*, 1888, p. 855.

Infusorial Earth, or Kieselguhr, sterilized by being subjected to a heat sufficient to cause it to glow, is said by Dr. Habart to be excellent as a dusting powder in surgery. It absorbs from five to seven times its weight of water. Mixtures of equal parts of the earth and salicylic acid, salol, or iodoform, as well as a 1 in 2,000 trituration of corrosive sublimate, have proved useful.

Ashes and Cinders.—In Belgium and Holland the household ashes are thrown daily into privies and ditches, with the idea of disinfection. In Salford, Oldham, and other places, the ashes, vegetable, and street refuse were formerly carbonised and used for the same purpose, sometimes with the addition of charcoal and dry earth, as recommended by Parkes. But though the odour is in great part removed for the time, and the excreta are solidified so as to facilitate removal, no true disinfection is accomplished.

Gypsum with coal-tar, under the name of *poudre de Corne et Desneaux*, was formerly much employed in France for disinfecting wounds.[1] Gypsum is still sometimes used in stables. Asbestos, talc, pumice, in fact any dry absorbent powder, will act nearly as well.[2]

Sand Filtration.

Sand filters were first regarded simply as strainers for turbid water, and the fineness and cleanness of the sand as the most important point. Analyses later proving that the soluble constituents were considerably affected, an explanation was sought in surface action. Afterwards from the fact that nitrates and carbonic acid were formed, a chemical theory of simple oxidation arose, involving a free supply of air.

Three discoveries, however, threw a new light on the process.

1. The size of the finer mineral particles is only about $\frac{1}{1\,5\,0\,0\,0}$ inch (0·25μ), and that of most bacteria $\frac{1}{2\,5\,0\,0}$ inch, or larger (μ to 5μ), but both are smaller than the interstices between the grains of even fine sand, consequently it follows (*a*) that the clearing is not accounted for by simple straining, (*b*) that the organisms would be retained first.

[1] Valpeau, *Comptes rendus*, 1860, p. 279.
[2] Vallin, *Désinfectants*, pp. 41, 56.

2. Piefke in Berlin, about 1886, found that sterilized sand effected hardly any purification and did not retain microbes. It had previously been noticed that sand filters did not become efficient for some days after re-laying.

3. When the oxygen or air, and the water were sterilized, little or no oxidation of organic matter occurred.

It was proved, therefore, that for the proper mechanical and chemical effects the action of organisms is essential. It must be remembered that some organisms have long flagella, while a large number, such as diatoms and bacteria, are normally surrounded by a gelatinous envelope which greatly increases their size, and enables them to adhere to surfaces, so that in a short time the sand in a new filter becomes covered with a living slimy layer which entangles suspended matters and effects the main part of the purification. This is called "schmutzdecke," and sometimes the "schlamm-decke," or mud-covering, and until it forms the filtration is inefficient.

In the under layers of sand the nitrifying organisms, which work best in the dark, act as they do in soils, causing oxidation, and producing nitrates by the aid of the dissolved oxygen. Green algæ in their growth evolve oxygen, and so increase the amount in solution, while bacteria as a rule diminish it. Although the chief removal of organisms occurs in the "schmutzdecke," the lower layers of sand are not inactive, as Reinsch has shown at Altona. For an example, he gives the average number of organisms per c.c. as:—Raw water, 36,000; just under the schmutzdecke, 1,800; at bottom of sand (35 inches), 44.

The proportion of micro-organisms removed by the sand filters of water companies shows ordinarily a variation between 95 and 98·5 per cent., but should be well up to the latter figure. Koch laid down as a limit that water containing more than 100 organisms per cubic centimetre must not be allowed to pass into consumption. That when carefully used these filters afford a remarkable protection against pathogenic species, was proved by experience in the cholera epidemic of 1892 at Hamburg and Altona,[1] when in Altona the water was filtered carefully, in Hamburg not. Although

[1]Koch, *Zeit. f. Hyg.*, vol. xiv., p. 393; vol. xv., p. 89.

the original water supplied to Altona was worse that that of Hamburg, the deaths in Altona were 221, in Hamburg 1,250, per 100,000. At the end of 1892 an outbreak occurred in Altona owing to a filter-bed breaking down, a proof that the slightest imperfection in the manipulation is a constant menace during any epidemic.

"Mechanical Filters," such as the Jewell type, are much used, especially in America, for purification on the large scale. The water is driven through a much smaller bed of sand or crushed quartz at about 40 times the rapidity. Coagulation by sulphate of alumina followed by lime, is generally adopted as a preliminary to form an artificial "schmutzdecke," or top film. Used in this way they are capable of removing 96 to 99·5 per cent. of the organisms. With or without coagulants they are specially suitable in cases where the supply has to be drawn from turbid sources, for preparing the water for the ordinary slow sand filtration, as they are much more easily cleaned and renewed than large filter beds.

Sterilizing Filters.

Sand and mechanical filters in good condition, and under favourable circumstances, occasionally yield a sterile effluent. But such a result cannot be depended on, and to secure it a much finer medium must be employed. At this date it is hardly necessary to refer to the large variety of filters formerly trusted, which have been proved by Plagge, Sims Woodhead, Guinochet, Johnston, and others, to be quite inefficient in preventing the passage of bacteria, though they may render the water bright in appearance. These filters were really worse than useless, as they formed a cultivation bed for organisms of all kinds, including pathogenic forms, and actually sometimes increased their numbers.

The only filter that has stood all tests is the Pasteur-Chamberland. This so-called "candle-filter" originated, as is well-known, from Pasteur's laboratory experiments in preparing germ-free broth cultures for bacteriological investigations, when Chamberland introduced the practical application to drinking water of the tubes that Pasteur had found efficient for excluding bacteria. The same remark applies to these as I have made in connection with sand filters, that the removal is not accounted for entirely by a

mere straining by the material, as the bodies of some of the organisms are smaller than the pores, though the gelatinous envelope of the bacteria and their entanglement, joined with the much greater fineness and evenness of the medium, and the consequent slowness of filtration, make the removal complete. But there must be also some molecular attraction dependent on the material of the tube and its manufacture, as a large number of fine-grained substances, to the naked eye apparently identical in texture, have been tried and found to be unreliable. Even with the Pasteur filter it is stated that "it requires the highest skill in pottery to produce a uniform result as to sterilizing capacity, and some 30 per cent. of the finished tubes are rejected on test." Candle filters are manufactured by the Sanitats Porzellan Fabrik, at Charlottenberg, and in this country several English-made candle filters have appeared. At present, however, there is no sufficient evidence to warrant the belief that any of them give the protection against water-borne disease which is afforded by Pasteur filtration, and the assumption that they function similarly is a very dangerous one for the general public, who are unable to distinguish between the forms.

Clark's process of softening by the addition of slaked lime to a water, whereby nearly the whole of the carbonate of lime is precipitated, has long been known, not only to soften the water, but also to carry down the greater part of the colouring matter and suspended impurities, mineral, organic, and living. Thus at Hampton, it has been found to reduce the germs in the Thames water from 1,437 per c.c. to 177.

Other Methods.—Among modifications of Clark's expired patent are Gaillet and Huet's, which consists in the addition of caustic soda and accelerating the separation of calcium carbonate by deposition between plates, and Maignen's Anticalcaire, which contains more soda, sodium carbonate, and lime, and throws down nearly all the lime and magnesia of the water.

Percy Frankland, in a comparison of the original Clark's process with that of Gaillet and Huet, as tried on the water of the Colne Valley Waterworks, found

	Germs before.	Germs after.	Reduction per cent.
Clark, after two days subsequent rest ...	322	4	99
Gaillet and Huet, after two hours	182	4	98

145803

so that the addition of soda very greatly increases the rapidity. It must be borne in mind that even if only 2 per cent. of the organisms are left, the water is not sterilized, but the subsequent addition of a relatively small quantity of a chemical disinfectant would secure such a result.[1]

Even waters containing a small number of organisms, such as those derived from deep wells, are bacterially improved. Thus, in my examination of periodical samples of a company's water from a deep chalk well, from 1899 to the present time, I found the average removal of organisms to be 67·6 per cent. It has been proposed to use lime as a precipitant in the storage reservoir, and a portion of the precipitate so formed as a coagulant to form the artificial top film in a sand or mechanical filter. At Cincinnati a process on these lines was tested in 1899, and it was found necessary to apply an excess of lime water in order that the fine clay particles might be aggregated into relatively large masses. With a suitable degree of coagulation, the effluent of the sand filter was brilliant in appearance, and very low in its contents of bacteria and organic matter. The water was rendered alkaline and was liable to subsequent precipitation, hence it was necessary to apply carbonic acid after the treatment. This is on the lines that had previously been used in England by Archbutt and Deeley in their well-known softening plant. A somewhat similar method of purification is contemplated for the supply of Washington, D.C. The use of lime as a coagulant in the storage reservoir also ensures the absence of plumbo-solvent properties in moorland soft and acid waters, and as the further bacterial removal required is less, the rate of the subsequent filtration, if resorted to, can be augmented.

Slow deposition alone diminishes the number of micro-organisms present in a liquid. In the passage through two settling reservoirs of the New River Co., Dr. P. Frankland found that the alteration in the number of germs present was as follows:—

	Germs per c.c.
Entrance of first reservoir	677
Exit ,, ...	560
,, of second reservoir (large one)...	183

Reduction 73 per cent.

[1]See also Kruger, *Ann. de l'Inst. Pasteur,* vol. ii., p. 621.

Buchner[1] introduced into clean water in repose a number of different micro-organisms. *B. pyocyaneus* multiplied abundantly, but *B. typhosus* and *B. coli* (the ordinary bacillus of the intestines) died in two or three days;[2] whilst Percy Frankland in Thames water, and J. Parry Lawes in London sewers, have noticed similar results.

Duclaux remarked[3] that putrefaction itself purifies, and the microbes themselves are the chief purifying agents. It is true that although they finally convert putrefying matter into carbonic acid, ammonia, nitrates, and water, which are harmless, in the process several transition products are formed which are very poisonous. Moreover, if they multiply within the body they produce disease by mechanical irritation, by starving the nutrition, or by excreting toxic compounds, such as ptomaines, etc., into the blood. It is necessary, therefore, (1) to keep their numbers within bounds, (2) to exclude or kill the specially dangerous ones, (3) in special cases, as in preservation of food, to get rid of them altogether. Such an end can be attained in the case of sewage effluents, first by accelerated deposition, second by chemical disinfection of the clarified water, and, finally, by subsequent irrigation and filtration through land.

Scott Moncrieff was the first to introduce on a practical scale the systematic use of organisms for purifying sewage, followed by Cameron, Dibdin, and others.

Further details on these subjects will be found in Rideal's "Water and its Purification," Crosby Lockwood, 1902; and "Sewage and the Bacterial Purification of Sewage," Sanitary Publishing Co., 1901.

Cold and Desiccation.

It is well known that damp and hot climates are the special seats of disease of an epidemic character, and that dry localities, whether cold or hot, are comparatively healthy. Moisture and warmth being favourable to the growth of micro-organisms, it might be supposed that cold and dryness would prejudice their vitality. To a great extent this is the case. But Melsens in 1870 published the fact that

[1] *Archiv. f. Hygiene*, 1892, p. 184.
[2] See also Schmidt, *ibid.*, vol. xiii., p. 247.
[3] *Ann. de l'Inst. Pasteur*, 1894.

the vitality of yeast cells was not destroyed by a cold of −100°C. Burdon Sanderson in 1871 asserted the presence of bacteria in ice-water from the purest ice.[1] Ianowski proved that snow even at − 3·9 to − 16° C. contained living micro-organisms,[2] Schmelk found the same in snow from a glacier in Norway,[3] Fraenkel in ice supplied from a lake near Berlin.[4] Pictet has also shown that the temperature of liquid air had no germicidal action. Macfadyen and Rowland cooled *Proteus vulgaris, B. coli communis,* and several other species of bacteria to − 252° C. by liquid hydrogen for 10 hours, without destroying their vitality. Doemens exposed yeast spores for six minutes to a temperature of − 190° C., and found that it exercised no appreciable influence on the power of development of the ferment or of admixed bacteria. Even the germinating power of barley was not injured under the same circumstances.

It has thus been proved that cold alone will not effect sterilization, although it inhibits the multiplication of organisms, especially the putrefactive ones, and pathogenic forms which thrive at blood heat.

The subject will be pursued in Chapter XIV.

The effect of *desiccation* follows similar lines in suspending the development of organisms, rather than destroying them. Sandy deserts show frequent remains of animals dried and free from putrescence. Desiccated flesh, herbs and vegetables, when well protected, have been kept for indefinite times. On the other hand, even among higher plants there are some species which, after drying, will revive on being restored to a moist situation, and the endurance of many seeds is well established. The same is the case with the spores of lower types; when perfectly dry they remain for the time sterile and inoffensive, and seem to be subject to aerial oxidation; but if, by the winds, or other agencies, they are carried in time to a moist situation, like a body of water, a plant, a human skin, or, still better, a mucous membrane (such as that of the lungs), they at once revive and commence to develop.

[1] *Thirteenth Report of Med. Off. of Privy Council.*

[2] *Centr. f. Bakteriologie,* 1888, vol. iv., p. 547.

[3] *Ibid.*, p. 547.

[4] *Zeitschr. f. Hyg.,* 1886, I., p. 302. See also Heyroth, *Arbeit. Kais. Gesund.*, vol. iv., 1888.

The utility of the *Eucalyptus* and other trees in marshy districts is partly due to their absorbing and exhaling the moisture of the soil. Siccative powders, like starch and steatite, are known to be useful in surgery. Many epidemics have suddenly ceased when a dry season has set in.

Both Koch and Klein have proved that the spores of most of the common species of bacteria resist drying for an indefinite period: the latter kept the spores of various micro-organisms—*e.g.*, *Peronospora infestans* (the potato blight), *Bacillus anthracis*, the hay bacillus, and those of scurf and jequirity, in culture tubes of agar-agar in a perfectly dry state—*i.e.*, in a closed bell-jar over oil of vitriol—until the medium had dried up to a thin shrivelled film; yet, even after two years and a half, on inoculating fresh materials from the above tubes, typical and good growths were obtained. On the other hand, non-spore-bearing bacteria—*e.g.*, various species of *Staphylococcus*, *Streptococcus*—bacilli of typhoid, swine fever, swine erysipelas, Koch's and Finkler's spirilla, the organisms of pneumonia, fowl enteritis, chicken cholera and grouse disease, as well as a number of others, were kept as agar cultures until the latter had well dried up: no sub-cultures could be raised from any of them. In other experiments they were dried in a current of air, or by simple exposure in a thin film on cover glasses in the manner employed by Koch, leaving them protected from dust till dry. No growth of the non-sporiferous species could be obtained in gelatine. If the drying is not complete, that is if the film be too thick, so that the superficial layer forms a protective coating for the rest, then the result of inoculation with such material will be positive; the bacteria below the surface, having been protected against drying, survive, and can produce a new crop. Similarly, when particles of solids containing bacteria are dried, it will be found that here also the centre escapes thorough drying, being protected by a superficial crust. Ordinary dust particles, however small, are never so dry that the bacteria contained in them are killed. The proof of this is that numbers of non-spore-bearing bacilli and micrococci can be cultivated from the dust of an ordinary room.[1]

[1] Klein, Stevenson, and Murphy's *Hygiene*, 1893, pp. 11, 81.

Dempster has pointed out that cholera vibrios, whilst they can survive in moist soil, quickly die when the land is dry.[1]

Dr. Buchner[2] says that in the dust of a room *B. tuberculosis* has been found alive a year after the patient died.

Provisions that have been smoked and dried may yet contain, not only micro-organisms, but also the ova of *Trichina* and worms. Pemmican, the dried and powdered beef of the prairies, has been said to communicate disease. If the meat, however, has been thoroughly soaked in a preservative like pyroligneous acid, and then dried, it is usually free from danger (*Koch*). Dry heat and superheated steam as disinfectants will be further considered in detail in the next chapter.

The Survival of Organisms in Soils.—With the object of throwing some light on disease epidemics, in which the closest investigations have absolutely failed to reveal any indications of the source of infection, and also in view of its bearing on the land treatment of sewage, the vitality and duration of pathogenic and other foreign bacteria in soil has recently been the subject of extensive investigations. R. H. Firth and Horrocks[3] have isolated *B. typhosus* from moist garden soil 74 days after it had been introduced, and from moist peat and dry sand 13 and 25 days respectively. These results are in close agreement with those of Professor E. Pfuhl, of Berlin.[4] Dr. Sidney Martin,[5] however, finds that the average duration of typhoid bacilli in cultivated soils is far less than this, and he shows that their survival depends to a great extent upon the moisture and temperature of the soils: in his experiments the bacilli were destroyed in a few days, both by a rise of temperature and an increased quantity of water. This is explained by his further investigations on the nature of this antagonism of soil to the typhoid, which appears to be mainly, if not entirely, due to a poisoning of the germs by the products of the putrefactive soil bacteria. The majority of these thrive and multiply

[1] *Brit. Med. Journ.*, March 26th, 1894.
[2] *Ohio San. Record*, April, 1894.
[3] *Brit. Med. Journ.*, Sept 29th, 1902.
[4] *Zeitschr. f. Hyg.*, xl. 3, 555
[5] *Local Government Board Reports*, 1896-1901.

extensively at a warm temperature, and in the presence of water thus exterminate the typhoid very rapidly. He has shown that typhoid may exist in fairly dry soils for 12 days, and that in cultivated soils that have been previously sterilized and then infected from a pure culture of *B. typhosus*, the bacilli even thrive and will be present in numbers after a lengthened period.

Dr. Houston[1] has infected soils with the organisms of cholera and diphtheria, and *B. prodigiosus*. The recovery of B. diphtheriæ from the soil when present in small quantity is doubtful, but presumably his results show that this organism is quickly exterminated. *Sp. Choleræ* rapidly decreases in number in surface soil, and its presence could not be demonstrated after a few days unless the soil was periodically dressed with liquid manure, when it was isolated after forty days. The number of *B. prodigiosus* was also rapidly decreased, but it was demonstrable in ordinary soils for a considerable time independent of previous sterilization. Experimenting with sewage organisms Dr. Houston[2] has found that these are also "crowded out" by the soil bacteria—the sewage streptococci were killed very rapidly, and even the spores of *B. enteritidis sporogenes* showed a partial disappearance.

CHAPTER III.

STERILIZATION BY HEAT.

HEAT AS A DISINFECTANT: Conditions required in a Disinfector—Modes of dealing with Condensation on Goods—Time and Steam Condition required for Disinfection—Experiments on the Penetrating Power of Steam—TYPES OF DISINFECTORS: English, French, Danish, German, American—Public Installations, English and American.

HEAT AS A DISINFECTANT.—There are circumstances in which chemical disinfection is not suitable, owing to the fact that many chemical disinfectants are very apt to cause damage to the articles treated, and also that their action frequently

[1] *L.G.B. Reports*, 1898-1899.
[2] *L.G.B. Reports*, 1900-1901.

involves prolonged exposure, and is even then only superficial in its effect. For instance, the usual mode of disinfecting rooms after infectious disease, is to close all outlets and burn a given weight of sulphur therein for a period of several hours. But if this treatment be applied to such things as heavy woollen clothing its effect is practically *nil*, as has been proved by numerous bacteriological tests. Surface disinfection is generally effectual in dealing with substances like wood, bricks, and iron, it having been assumed that all permeable articles, such as carpets, curtains, etc., have been previously removed for more complete treatment.

The use of heat for purifying purposes might have appeared an obvious step, but it must be remembered that nearly two centuries ago, disease germs considered as organisms of any kind, still less as bearing spores, were unknown, and, if their existence had even been suspected, considerable experimental proof would be required to show that a temperature below that at which articles of clothing would be damaged or weakened in their fibre, would be sufficient to destroy all danger of infection. The work of Needham, therefore, during and before 1743, must be looked upon with admiration, since it was he who first recorded experiments in a systematic manner involving the use of heat with the object of sterilizing organic substances. His cultivations, as they would be termed to-day, were placed in carefully-closed vessels surrounded by fire, and his experiments led him to conclude that such treatment rendered growth impossible. Curiously enough an after-growth in the sterilized cultivating medium made him a convert to the theory of spontaneous generation, and it was in reference to this theory, the crucial debate of the age among scientific men, that the publication of his experiments was due.[1] Needham's great opponent, Spallanzani, in reference to the same theory, also took up the question of sterilization by heat; he even went so far as to detect the difference between dry and moist heat, and showed that in some instances animal life was impossible in water at 45° C., whereas the

[1] See *La génération spontanée*, by I. Strauss; *Arch. de médecine expérimentale*, t. 1er, pp. 139-156 and 329-348.

same cultivations were not destroyed by dry heat at a temperature less than 80° C.

In 1804, Appert discovered that meat, vegetables, etc., when placed in carefully sealed receptacles, and dipped in boiling water for an hour, would keep indefinitely without putrefaction or fermentation. This process was very carefully reported on by Gay Lussac (at the request of the French Government), who, owing to these investigations, expressed the opinion that no oxygen was present in the sealed vessels after the process, and that the absence of this gas was essential to the preservation of animal or vegetable tissue; but it was noteworthy that, although this *brochure* was for long regarded as the standard work dealing with the subject, no mention whatever was made of the destruction of germ life within the vessel.

It is generally believed, however, that the earliest application of heat to disinfection on a large scale, as opposed to the laboratory experiments of Needham, Spallanzani, etc., was not made public until Dr. Henry, F.R.S., of Manchester, gave an account in the *Philosophical Magazine* for 1831, of some experiments he had made on the disinfection of infected clothing by hot air. A steam-jacketed copper was used, into the casing of which only steam at 100° C. was admitted; but, apparently, it was found impossible to heat the interior to much more than 93° C. with these appliances. Dr. Henry's results, so far as they went, were encouraging, and tended to show that the clothing of scarlet fever patients, which had been submitted to a temperature of 93° C. for two to four hours, would not propagate the disease if worn by other healthy persons. Most of Dr. Henry's experiments, and even of those of Dr. Baxter in 1875, were made with vaccine lymph, and it was really not until the experiments of Pasteur, Lister, Burdon-Sanderson, Tyndall, and Koch had been published, that sufficient data concerning the reality and nature of bacteria existed to render it possible to test the efficacy of heat, dry or moist, as a destructive agent.

The results of Tyndall's experiments (communicated to the Royal Society in 1876 and 1877, and also contained in his well-known book, entitled *Floating Matter of the Air*) were remarkable, inasmuch as they treated the subject largely

from the physicist's standpoint. In this work he proves conclusively how very variable is the influence, both as regards duration and intensity, of the heat essential for the sterilization of organic matter. He showed, for example, that hay infusion might be kept continuously boiling for several hours and yet not be sterilized, inasmuch as the spores could resist such treatment and develop subsequently, although the original mature bacilli would have all been destroyed. As a proof of this he boiled similar infusions intermittently for a couple of minutes, twice or three times during a day or so, and found that, although the total period of actual boiling might be less than six minutes, compared with the hours of the previous case, no aftergrowth whatever appeared in the preparation.[1] Tyndall also pointed out, and proved in some cases, that oxygen was an essential to the existence of micro-organisms. He found that 180 minutes continuous boiling failed to sterilize a turnip infusion in the presence of the ordinary supply of air, but that ten minutes at 100° C. sufficed to produce absolute barrenness, when such heating was conducted in absence of air. The production of vacuum was found to be such an important factor in sterilization that experiments were made to ascertain whether the total absence of oxygen would in itself be sufficient to effect destruction, and in so many instances was this found to be correct, that the conclusion was arrived at that, with sufficiently perfect exhaustion, all infusions would probably be sterilized.[2]

The views of Tyndall, in reference to the necessity of oxygen for the propagation of microbes, have since been much modified by the experiments of later observers, who discovered that a small class of bacteria, called "obligatory anaerobes," could only exist in the absence of oxygen, and that others, "facultative anaerobes," increased most in the presence of free oxygen, although it was possible for them to exist in the absence of this gas. The latter class is the larger of the two, and includes many pathogenic organisms, such as the *Bacillus anthracis*, and the bacillus of Asiatic cholera. There is also a third class, "obligatory aerobes,"

[1] Such a procedure has been adopted for the preparation of culture media, and is called "fractional sterilization."

[2] *Comptes rendus*, vol. lxxx., p. 1579.

to which the presence of oxygen is an absolute necessity. The observations of Tyndall are, in this respect, not perfectly accurate, although it is probable that his conclusions would hold true for the larger number of cases for which disinfection is required, insomuch as clothing is constantly aerated, and, therefore, should, under ordinary conditions, contain no living obligatory anaerobes.

The foregoing results are of the greatest importance from the practical standpoint, as will be seen later on. They paved the way for further progress at the hands of Koch, Pasteur, and others.[1] Koch made his experiments on *pure* cultivations of (1) non-spore-bearing organisms, such as the *Bacillus prodigiosus;* and (2) of spore-bearing kinds, such as anthrax bacilli, etc. He attempted disinfection by chemical agency, hot dry air, and by steam; moreover, in all these cases the trials were eventually made on a sufficiently large scale, with bedding, etc., to make his results of the greatest value. He confirmed, generally, the observation of previous workers that the spores were the most difficult to destroy, and that, therefore, if they be devitalised, all bacteria will also have been rendered harmless. In dealing with hot dry air he found that spores were only destroyed by being exposed at 140° C. for a period of three hours, but that at this temperature[2] almost all fabrics which require disinfection are already injured, and that the rise in temperature inside a small roll of blankets so exposed was not sufficient unless the exposure was continued for a much longer period. When steam at 100° C. was used as a disinfecting agent, Koch found that anthrax spores, when freely exposed, were killed in five minutes, and that even with steam at atmospheric pressure, penetration of heat through blankets took place in about one-quarter of the time necessary to secure a sufficient internal temperature when hot dry air alone was used. From the medical point of view, these experiments were most satisfactory, although, owing to the crude nature of the apparatus used, it would appear that most, if not all, the articles treated were considerably moistened and in some cases damaged by the action of the steam.

[1] *Mittheilungen aus dem K. Gesundheitsamte.* vol. i., p. 188.
[2] See also *Brit. Med. Journ.,* September 6, 1873.

Hoch and Wolfhügel[1] conclude that "dry heat, even continued for two hours at 150° C., did not always assure disinfection, although nothing resisted, even for a few minutes, boiling water or steam at 100° C." Gaffky and Löffler[2] summarise their experiments as follows:—

1. Non-spore-bearing bacteria cannot endure for one and a-half hours an exposure to hot air at 100° C.

2. The spores of mould are not killed by one and a-half hours exposure to hot air at 110° to 115° C.

3. The spores of bacilli are only killed by three hours exposure to hot air at 140° C.

Bonhoff and Foster[3] state that *Bacillus tuberculosis* at 60° C. dies in one hour, at 90° C. in five minutes, and at 95° C. in one minute.

Von Schomberg in 1902 (*Zeits. Hygiene,* xli., 167) found that even the most permanent of the pathogenic bacteria *not bearing spores,* when present in articles of clothing, were destroyed within an hour by air at 100° C. if its relative humidity were 55 to 65 per cent. He obtained this condition by placing vessels of water in the chamber, not too near the source of heat. He found that leather articles were not affected, and do not shrink even after six to eight hours, and that dyed fabrics were unchanged. He confirmed previous results as to the imperfect action of *dry* hot air, and as to failure of the above method for spores.

The experiments of Dr. Klein and Dr. Parsons, as detailed in the *Annual Report to the Local Government Board for* 1884, support very largely those of Koch, and they also deal with the question of practical disinfection in a manner that renders this work of very great value. The great advantages of steam over hot air were demonstrated very clearly, and, owing to the number and diversity of their experiments, they were able to show that, in some cases at all events, the action of steam in a suitable apparatus was not in itself injurious to the articles treated.

"Saturated" steam—*i.e.*, steam at the temperature at which it can directly condense into water—penetrates bulky

[1] *Mitt. a. d. Kais. Gesundh.,* 1881, p. 301.
[2] *Ibid.,* p. 322.
[3] *Hyg. Rundschau,* vol. ii., p. 869.

and badly conducting articles much more rapidly than dry heat. In entering the interstices of cold bodies steam undergoes condensation and imparts its latent heat to the objects in contact with it. At the same time, as water, it occupies only about $\frac{1}{1800}$ of its former volume. To fill the vacuum thus formed more steam enters, and so on until the whole mass has been penetrated. On the other hand the contraction of hot air in cooling is very much smaller; being, for each 1° C., $\frac{1}{273}$ of its volume at 0°. As an example, 394 volumes at 121° C. would become 283 volumes at 10°, a contraction of only about 28 per cent.

The work of Pasteur, Tyndall, Lister, Koch, Parsons, and others, has, therefore, determined the fundamental conditions for successful disinfection by heat.

Conditions required in a Disinfector.—It remains to be shown that the mechanic can meet the requirements of the bacteriologists, and, at the same time, deal with the practical difficulties that invariably arise during the introduction of novel machinery. The conditions for dry-heat disinfection, so far as temperature and duration of exposure are concerned, have not been very clearly defined; but from experience gained by Dr. Hopwood at the London Fever Hospital, it may be gathered that an exposure of bedding to hot air at a temperature of 121° C. for a period of nine hours is generally sufficient, and no material damage is caused thereby to the goods.

The great difficulty in designing a stove to fulfil these conditions arises from the fact that it is almost impossible to obtain a uniform equable temperature in a sufficiently large chamber. Exposure to air at a temperature of 127° C. for nine hours weakens many woollen materials, and a temperature of 138° C. distinctly discolours them, whereas an error of five or ten degrees on the lower side of 121° C. renders disinfection by these means uncertain. The allowable range of temperature in a hot-air disinfector should, therefore, not exceed 10°, and the mean should be about 121° C., since, according to Drs. Parsons and Klein, the free exposure of anthrax spores to air at 118° C. for one hour suffices for their destruction.

Most engineers are well acquainted with the great difficulty met with in heating air to a uniform temperature,

and the problem is not made any the easier by the fact that in such places where hot-air machines are now required, steam is not available for heating the air. If steam were at hand there can be little doubt but that it would be employed for the actual disinfection without the aid of air. Where coal and gas are the only practicable sources of heat, seeing that it is merely in the smallest and most out of the way districts that hot-air disinfectors are permissible, the first cost of the apparatus may have to be kept so low that adequate temperature-regulating becomes almost impossible to provide for in a chamber of the requisite capacity. The dimensions must be determined by the size of the largest article that may require disinfection. It becomes especially important to arrange the objects in such a manner as to reduce to a minimum the distance through which heat has to penetrate, and, therefore, bulky things, such as mattresses, should never be doubled, and if several have to be treated at once, each should be separated from its neighbour by wooden strips to allow of 2-inch or 3-inch air space. This rule as to non-folding enables us to fix upon a length of 6 feet as a minimum, at any rate for the diagonal of the chamber. One dimension being thus defined, another may be determined in a similar manner by the width of the mattress, which in hospitals or public institutions is not usually over 3 feet, but in private households very commonly exceeds 5 feet. It may, however, be assumed that in the future no *public* hot-air disinfectors will be erected, and that their very limited scope will be confined to small workhouses or institutions; hence, after allowing for a small margin, a depth of four feet should suffice. The width will depend on the number of articles likely to require disinfection at one time. Thus four mattresses each 6 inches thick would require a chamber about 3 feet wide, after making sufficient provision for air space between each unit. As a matter of fact the smallest hot-air disinfecting chamber usually erected in this country is 4 feet 6 inches long, 4 feet 6 inches high, 4 feet 6 inches wide internally, and in this an ordinary 3 feet by 6 feet mattress must be placed diagonally, a very unsatisfactory arrangement, owing to the available space being so much cut up, and also because the ends of the mattress rest actually in the angles of the chamber,

where it has been ascertained that a certain quantity of "dead" (*i.e.*, unchanged or stationary) air generally remains at a temperature considerably lower than the average throughout the closet. The latter objection attends the majority of rectangular disinfectors, but if the size be ample, the dead air spaces need not actually be occupied by portions of the charge.

Gases being very bad conductors, and almost all the heating effect being accomplished by convection, a free circulation of air through the chamber becomes of great importance. There is always a certain risk of overheating the goods, and in most cases they are temporarily weakened, and perhaps rendered brittle, immediately after their removal, although these latter defects usually disappear after the articles have regained their normal hygrometric moisture. Means must be provided for extinguishing an accidental fire in the chamber, as for instance from matches left in pockets or linings. A common device is to stretch across the chamber a chain with fusible links at intervals, connected with a damper which closes the air inlet immediately the chain is severed by undue heating, and also closes the tap where gas is used. The clothing, however, may have been already destroyed.

Dr. Parsons' *Report* of 1884 gives full particulars of the dry-heat machines then in use. He found that very few, if any, fulfilled all the conditions required for adequate disinfection, although he mentions Bradford's apparatus as being the best coal-fired disinfector, and the invention of Dr. Ransom as being a very suitable gas-heated machine. The former contained an exposed dish of water during the experiments, whereas the latter did not; although there is no apparent reason why such an addition should not be made, if found advantageous. In the Bradford apparatus, a range of temperature of 13·3° was found to exist throughout the chamber, the maximum being about 120° C. The moistening of the air was found to have an appreciable effect in aiding the penetration of the heat, and thus diminishing the period of exposure, and in Mr. Bradford's opinion it also tended to preserve fabrics from injury at high temperatures. On the other hand, it is clearly difficult to so stoke a fire as to produce a uniform temperature in a large

chamber—even opening the furnace door caused a fall of 4 degrees—and the success, or otherwise, of the process must, therefore, largely depend upon the skill and attention over several hours, of the person in charge. No experiments with bacteria appear to have been made in either machine.[1] In Dr. Ransom's apparatus the temperature may be automatically governed by a regulator, and on trial a variation of 5 degrees was recorded in the chamber, the minimum being 119·4° C. Although the time taken to attain the required heat and to disinfect is considerable, the apparatus can be left with safety to work without attention, owing to the gas regulator. A constant stream of heated air passes through the machine, which tends to preserve uniformity of temperature, and partly accounts for the superiority over coal firing.

Besides the drawbacks of slowness, and the danger of damaging the goods, it has been found that the hot air process offers facilities, or even encouragement, to the man in charge to scamp his work, for one can rarely tell by the appearance whether articles have been disinfected or not; and so great is the risk of articles firing or being singed, if subjected to a temperature of 121° C. for several hours, and thus bringing the attendant into trouble, that, as often as not, he takes the precaution never to allow it to exceed 93° C. In one instance in 1894, at a dry-heat disinfecting station in a densely populated London district, the attendant actually prevented the air rising above 88° C. because expenses had been incurred in the past for the replacing of damaged clothing. This farce had been going on for many years. Since 1895, no new apparatus involving the use of hot air has been introduced, so that at the present time the different forms of steam disinfection only are attracting attention.

Steam Disinfectors.

In a well-constructed steam apparatus the temptation we have just referred to is removed, as there is no danger of injuring the fabrics, and the required temperature is obtained independently of the attendant after his steam valve has

[1] A later modification of Bradford's apparatus uses steam superheated by coils; the firm have also adopted a high-pressure steam disinfector.

once been opened. The superior germicidal and penetrative qualities of steam have already been referred to, and the only drawback to its adoption is that, unless proper precautions are taken, the steam may condense on the articles in sufficient quantities to damage them, and to necessitate drying, subsequent to their removal from the machine.[1]

Modes of Dealing with Condensation.—This question of condensation roughly divides the several types of steam disinfecting apparatus into two classes, viz., firstly, those in which provision is made to prevent copious condensation by keeping the walls of the chamber at a higher temperature than the steam inside; and, secondly, those in which no such provision is made, and which frequently necessitate, as a consequence, the subsequent drying of goods. Each of these classes might be further subdivided into several others, determined by the pressure of steam admitted to the chamber, by the currency or otherwise of the steam in contact with goods, and by the introduction or addition of apparatus necessary to create a vacuum in the chamber. Special apparatus has also from time to time been made to overcome special difficulties, such as arise when heavy bales of rags or merchandise have to be treated in large quantities. In the usual practice the steam admitted to the outer casing is hotter than that subsequently passed into the chamber. Although in this way the condensation from contact with cold walls is obviated, the articles themselves condense at first a certain amount of steam, being at the same time warmed by the latent heat of the liquefaction. This will continue until the goods have reached the temperature of the surrounding space, when the outer jacket will commence to heat the steam inside and to keep it circulating by convection, so that the moisture will be re-evaporated, and the goods can be removed substantially dry. Safety and reducing valves keep the pressure constant. It is found in practice that surprisingly little injury is done to fabrics; even the colours in cheap cotton print show no signs of running, while delicately-tinted silk dresses are but little

[1] See v. Esmarch, *Zeitsch. f. Hyg.*, Bd. iv.; Gruber, *Gesundheits ingenieur*, 1888; Budde, *Archiv. f. Hyg.*, Bd. ix.

affected by the initial condensation. Some materials lose their gloss, and certain other woollen goods, such as new blankets, take the slightly yellow tinge that would generally follow a good washing; the only goods which are absolutely damaged are those made of leather, or fur. These latter should always be treated by dry heat, or other means, and the same remark generally applies to varnished or glued woodwork, although heat of either sort when applied to finished woodwork almost invariably leaves a record of its application of a more or less serious nature.

Time and Steam Conditions required for Disinfection. These depend on three main factors—viz., firstly, on the particular disease germ that it is required to kill; secondly, on the nature and bulk of the articles supposed to contain the germs; and lastly, on the steam pressure employed to secure penetration into the goods. It is, of course, impossible to say whether any article contains only one species of microbe, and also it is very frequently found to be practically advantageous to treat at one operation the clothing, etc., of patients suffering from several distinct maladies. The minimum period adopted should obviously be that required for killing the most resistant organism. Dr. Klein and others have found that the highly resistant spores of *B. anthracis* furnish a very good test, and, judging from their experiments, it appeared that a free exposure to saturated steam at 100° C. for fifteen minutes was a period in which sterilization could be effected with certainty. It was found that five minutes exposure under the same conditions gave doubtful results, and, therefore, it is probable that absolutely safe disinfection cannot be effected with steam under less than ten minutes free exposure. This period was also found just sufficient to kill lice and their eggs, for which purpose these machines are sometimes almost entirely used in such places as workhouses. The germicidal effect of saturated steam at a higher pressure of, say, 15 or 20 lbs. per square inch is usually supposed to be greater than that of steam at atmospheric pressure; in fact, Dr. Klein considered that its efficacy might be taken for granted, and, therefore, made no experiments of a similar nature by its aid. There is, however, one point to which attention should be drawn; steam may be either "saturated" or "superheated," but

the germicidal influence of the two is now recognised to be different, although the steam is dry in both conditions, and either form may exist at any pressure or in the absence of water. These two facts are mentioned, because, in the minds of some, saturated steam is commonly associated with moisture, and superheated steam is confused with steam under pressure. The two forms are distinguished entirely by their temperature—that is to say, steam may just exist at 109° C. under an absolute pressure of 20lbs. per square inch (*i.e.*, including atmospheric pressure), or by adding more heat to it, its temperature will rise, say, to 149° C. at the same pressure although its volume will increase, and in this condition it is said to be superheated. In most, if not all, steam-jacketed machines the earlier portions of the operation must perforce be conducted with saturated steam, and in the better machines, from which the articles come out absolutely dry, it is probable that the steam contained in the chamber becomes slightly superheated towards the end of the process. Hence, it matters but little in a jacketed machine whether saturated or superheated steam be the better disinfecting agent, for steam may be used in both conditions. As a matter of fact, the difficulty has always been to bring the articles out dry, and so long as they come out with even ½ per cent. added moisture, it is certain that the steam has never been entirely superheated.

The question of steam pressure to be employed is one which has been much debated, and at the present time there are machines (mainly on the Continent) which employ steam at 1½ lbs. pressure; and others again working with steam at 20 lbs. pressure. Assuming, for the sake of argument, that the higher pressure steam has no greater germicidal effect than the lower (which is not probable), it still has many important practical advantages which are of great value in most cases. When bulky articles, such as mattresses, rolls of carpets, etc., have to be treated, or when the machine must be filled so entirely that the air space between each article almost disappears, then it is clear that penetration of 20 lbs. steam will take place far more rapidly than if this pressure be only 1 or 2 lbs. Or, again, a machine which uses steam at 20 lbs. pressure may be worked off almost any existing boiler, because almost all steam generators nowadays work

at pressures above that required, and, although it is a comparatively simple matter to reduce the pressure automatically to 20 lbs., it is not nearly such an easy problem to reduce the pressure sufficiently so that the steam may be used with safety in apparatus designed to stand 1½ lbs. only. This difficulty may entail the erection of a special boiler of unusual design, and steam is then raised under conditions the reverse of economical. It is also noteworthy that condensation is more likely to take place when low-pressure steam is used than when steam at a higher temperature is admitted. The main objection to high-pressure apparatus is that the machines require not only greater strength, but also more careful design, and are consequently more costly. There are occasions, doubtless, when, on economical grounds only, the low-pressure machine is allowable; but the circumstances, even in these cases, should be such that time for drying articles can always be allowed subsequent to treatment. Although steam can, as has already been shown, penetrate the bulkiest article in a comparatively short time, this period may, by a little manipulation on the part of the attendant, be very materially reduced. In arranging the goods in the chamber, every care should be taken to leave a little space between each of the various rolls or bundles. Often a few pieces of wood or a rough hurdle may come in very useful when articles have to be piled one on the other, or things can be hung up readily so as to allow of circulation. In all cases it is safest not to permit the attendant to handle infected articles more than is absolutely necessary; therefore, bundles or rolls ought not to be themselves unpacked, although such a proceeding would undoubtedly hasten the process. Again, after the chamber has been closed (assuming it to contain bulky articles), penetration may be greatly facilitated by relaxing the pressure and refilling several times during the process. Thus, if the chamber be filled with steam at 20 lbs. pressure in two minutes, this steam may be allowed to remain stagnant for say two minutes, and then allowed to escape. It should immediately be refilled with steam, and perhaps five minutes later again allowed to escape, and so on. It is probable that this procedure is advantageous owing to the large amount of air retained in woollen and other goods, which is compressed

by the steam into their centre, and if not allowed to distribute itself throughout the chamber by removal of pressure, would greatly retard penetration. It has been found that rolls of blankets, rolls of carpets, and compressed bales are among the most difficult articles to disinfect, and in such cases the precautions just referred to should most certainly be adopted. Mattresses and pillows can readily be separated one from another, but if this be not done, considerable time may be required for these also. There is still one difficulty which arises when heavy charges are placed in the machine, and that is due to the internal condensation in the centre of the goods. The explanation of the causes promoting condensation will have made it clear that such difficulties will be more difficult to eradicate in large bundles than in small ones; and, as a matter of fact, it is generally the rule that moisture will be perceptible in the centre of a large roll in spite of the steam jacket. It is clear that condensation may be entirely avoided in the first place if the goods be raised to the temperature of the incoming steam prior to its admission; but it has been shown that in dry-heat stoves it is a very lengthy operation if the goods be bulky. The length of time is due very largely to the fact that the hot air is not forced into the centre of the goods; in fact, it has little more than a surface action, and, as a consequence, the goods usually act as a capital non-conductor to protect the interior, and the cold air retained there. But if we assume that this contained cold air could be withdrawn, and the hot air subsequently forced in to take its place, we get a very different state of things, and the heating can obviously be effected far more rapidly. This course is practicable if steam be available, but the removal of air and the compulsory substitution of other heated air, absorbs more work than could be expected from an attendant if steam power were not at hand, as is the case when dry-heat disinfectors are employed.

The whole process may be completed by merely creating vacuum in the chamber and then admitting heated air at atmospheric pressure. It is a very easy matter to withdraw the bulk of the air by a simple steam jet, arranged after the fashion of the ordinary spray-producer, until a vacuum of 20 inches is indicated on the gauge; and then, if the chamber be placed in communication with the atmosphere,

air is forced in at a pressure of about 10 lbs. to the square inch, and, in transit, it may be passed through a short coil of pipe surrounded by steam at the required temperature so as to heat it to the most suitable degree. There are many features about this process to recommend it; for, not only is it possible to regulate the temperature of the incoming air to a nicety, but it is also itself easy to heat, because it is constantly in motion, and, for the same reason, the hot air itself heats the goods it comes in contact with the more rapidly. If the air be passed through pipes heated by the direct heat of a fire, it becomes almost impossible to control its temperature, and the same dangers of scorching arise as were found by the use of dry heat stoves. In the class of apparatus described it has been found desirable to keep the temperature of the incoming air to about 105° C., so that, when steam is admitted at 121° C., it does not become superheated, and its germicidal influence is not affected. Supposing, for the sake of argument, that moisture still remains in goods after steaming, the presence of the vacuum and hot-air apparatus is still of great value; for by its aid the articles may be dried to any extent desirable at a far lower temperature than 100° C. The vacuum has several other advantages quite apart from its drying qualities. It enables the operator to remove most of the air from the chamber before the admission of steam; consequently, the ordinary steam pressure gauge may be read accurately as a temperature gauge, seeing that the mixture of steam and air has not to be considered, whereas the temperature of saturated steam varies with its pressure.

Also, the production of a good vacuum[1] prior to the admission of steam is equivalent to raising its pressure, so far as its penetrative power is concerned; consequently, the rapidity with which bulky articles are disinfected is very much increased, although the temperature at which they are treated remains unaltered. It thus becomes possible to disinfect goods with steam at only 10 lbs. pressure as rapidly as with steam at 20 lbs. pressure, when no vacuum is created.

[1]The term *vacuum* is not intended to imply the total absence of gases; a space filled with a gas, and under a pressure equal to that of 20 inches mercury as measured by the vacuum gauge, would be generally referred to as a fairly good vacuum.

Both these points are of importance, since of late years the practice has become prevalent to treat very bulky things, such as rolls of carpets, compressed bales, etc., and as the amount of work to be done is thus much increased the disinfecting chamber is commonly packed closely. Moreover, the damage done to delicate fabrics, which sometimes lose their gloss at 121° C., may be entirely avoided by disinfecting at say 105° C., without any increase in the time required to secure penetration. Altogether, the advantages to be gained by the introduction of this inexpensive and simple vacuum apparatus are considerable, and great credit is due to the inventors (Mr. J. B. Alliott and Mr. J. M. C. Paton).

Experiments on the Penetrating Power of Steam.—An idea of its powers may be gathered from a comparison of the following two trials. In p. 296 of Dr. Parsons' report it is stated that a cotton rag press-packed bale was tested in a Washington-Lyon machine. The dimensions of the bale were 3 feet 6 inches × 3 feet × 2 feet 3 inches, and its weight was 5 cwts. At the end of four hours a thermometer at its centre registered 125·5° C., and the increase in weight was 4·8 per cent. Experiments were made in 1893 with a similar machine, but fitted with the vacuum apparatus, on a press-packed bale of cotton rags weighing 5 cwts. 3 qrs. 13 lbs., and measuring 3 feet × 2 feet 4 inches × 4 feet 6 inches. The trial was conducted on similar lines, and every precaution was taken to prevent the passage of steam down the hole through which the thermometer had been admitted, by plugging it up with a long conical piece of wood larger in diameter than the hole itself. The thermometer was so arranged that when the mercury column reached a height equivalent to 105° C., an electric bell was rung outside the chamber. The bell rang precisely forty-five minutes after the introduction of the bale to the chamber, and it was removed after a final drying by the vacuum and hot air for a further period of thirty-three minutes. The whole time taken was seventy-eight minutes, and the total increase in weight was less than 2·6 per cent. The bale was again submitted to the air-drying for fifteen minutes, with the result that the moisture was further reduced by 30 per cent.

The accompanying chart shows the mode of working adopted during this trial, although it would probably have

hastened the process had the alterations of pressure and vacuum been more frequent, and it was also a mistake to have admitted the steam immediately on obtaining the first vacuum, instead of admitting and extracting hot air prior to the admission of the steam. The particular trials referred to are not such as will have to be frequently repeated in public disinfecting stations, but they have been given merely as indicative of the greater penetrative and drying powers of jacketed disinfectors when fitted with vacuum apparatus. If bedding or clothing has to be treated, the duration of the process is considerably shorter in either form of apparatus; but there still remain the same advantages in favour of the machine fitted with the vacuum apparatus.

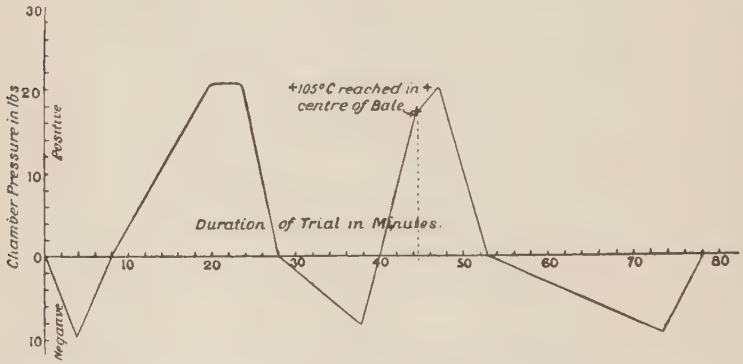


Fig. 1—Chart showing effect of vacuum of apparatus on the penetrative power of steam.

English Apparatus—Washington-Lyon's Patent.—In this country the machines mostly in use are those made under Washington-Lyon's patent. This is largely owing to the far reaching nature of Mr. Lyon's specification, on which much litigation has taken place. Generally speaking, these machines are made in two forms, square and oval in section.

The square form, made by Goddard, Massey & Warner, of Nottingham, is jacketed all round the body, in addition to the two doors. The jacket in this case is usually half filled with water, and is used as a boiler. The firegrate is placed immediately underneath, and the firebrick flue is built to traverse the bottom, and thence along other flues, built around the sides of the machine, to the chimney. The

steam pressure in the jacket (*i.e.*, the boiler) is usually limited to 20 lbs., and disinfection is carried on by steam at the same and lower pressures. Arrangements are also provided for passing through the chamber, before and after disinfection, a current of air heated by passing through a pipe situated in the furnace flue immediately under the disinfector, and circulated and extracted by means of a small exhauster. This apparatus has had a considerable sale owing largely to its rectangular form, and there can be little doubt that it disinfects adequately, and also that when properly worked there should be little or no moisture left in the goods. Its price is also a factor in its favour, although if the cost of the necessary brickwork setting and side flues be added to the cost of machine and erection, this advantage is more apparent than real. Its chief disadvantages are, curiously enough, precisely due to those features which are presumably advantageous. For instance, the square shape is to some an attraction, whereas it is undoubtedly a constructive weakness, and for obvious reasons the most suitable section for a steam chamber to stand a considerable internal pressure would be circular. Thus this advantage has to be paid for in the shape of repairs to leaky joints, insurance, etc., although possibly, in certain cases, it may be worth the risk. Again, the use of the jacket as the boiler is advantageous, inasmuch as less space is required; but, on the other hand, it is an imperfect boiler, which cannot be got at properly for cleansing, and is likely to be the cause of mishaps, especially at the bottom (which is not readily accessible for examination), where the fire impinges directly on the flat plate, and gradually burns it away. The presence of jacketed doors is also a feature of this machine, although it is doubtful if this additional complication is necessary when the hot-air apparatus is also supplied. The air is heated by the action of the hot gases of the fire, and the only precaution that has to be taken in reference to this point is to warn the attendant not to raise too large a fire when using the hot-air blast; for, if this point be not considered, the air may attain a scorching temperature, and so damage the contents of the chamber.

The size of this disinfecting chamber is usually 5 feet × 5 feet × 6 feet 6 inches internally, although machines of

smaller dimensions are also made. The following experiment with a new machine in 1893, gives an idea of the working of this apparatus:—

The fire was lighted at 10.8 a.m., the water in the jacket being cold, although the brickwork was still warm from the previous day's work. At 11.45 a.m. the pressure gauge showed 10 lbs. steam pressure, and at 12.0 noon it indicated 19½ lbs. pressure. The total time occupied for raising steam took one hour fifty-two minutes, and about 1 cwt. 1 qr. of coal had been consumed. The door was then opened for the admission of clothing. Three minutes were occupied in opening and four minutes in closing the door. At 12.10 p.m. the exhauster was set to work, and hot air was drawn through the chamber until 12.20 p.m., ten minutes in all. The chamber pressure gauge reached 5 lbs. at 12.20½ p.m.; 10 lbs. at 12.21½; 15 lbs. at 12.23; 19 lbs. at 12.27; and 20 lbs. at 12.31. During this period, from 12.20 to 12.31 p.m., the jacket pressure fluctuated between 19 and 20 lbs. At 12.23 p.m. the steam escaped freely from one of the doors which had presumably slightly sprung. This happened again subsequently, and had to be remedied by tightening the bolts securing the doors. At 12.31 p.m. the addition of feed-water to the boiler caused the pressure in the chamber to fall to 17½ lbs. Steam to the chamber was shut off at 12.35 p.m., and the chamber was then exhausted. From 12.35½ p.m. to 12.44½ p.m. hot air was again drawn through the chamber, and the door was opened at 12.48. A certain amount of vapour escaped through the door on opening, and some water was found at the bottom of the chamber. The goods which were hung up, consisting of overalls, were fairly dry and not damaged. A maximum thermometer which had been exposed in the chamber registered 127° C. The total process of steam raising and first disinfection occupied two hours and forty minutes, and the total fuel used amounted to about 1 cwt. 2 qrs. The time for disinfection only after steam had been raised was forty-eight minutes.

Dr. Whitelegge has been good enough to give the following figures relating to some trials made with this apparatus at Leicester in 1889. The process was similar to the foregoing, but the total time occupied was only twenty-seven minutes, which, apparently, was too little to secure penetration. The following are his results:—

When removed after disinfection, a horsehair pillow, weighing originally 2 lbs. 8½ ozs., was increased 1¾ ozs. in weight; it was damp inside, but dry on cooling. The thermometer in centre indicated 116° C. A flock pillow was increased only ½ oz., the initial weight being 3 lbs. 8½ ozs. This was also damp inside, but dry on cooling. The thermometer at centre showed 112° C.

Three blankets, each folded into 16, piled one above the other on the floor, were wet at centre and bottom even on cooling, and

the thermometer at centre indicated 74·5° C. Dr. Whitelegge also took the temperature of the chamber at different parts when the hot air only was admitted.

Temperature in hot air inlet, touching the pipe, was ... ... 143° C.
,, on pillow, 1 ft. from inlet, was ... ... 122° C.
,, on floor near inlet, was ... ... 119·5° C.

The temperature in chamber due to radiation and convection only, with and without air current, was as follows :—

The middle of floor after 15 mins. = 115° C., or after 5 mins. with ejector only 114°C
,, roof ,, = 118° C., ,, ,, ,, 121° C.
The roof near door ,, = 115° C., ,, ,, ,, 119° C.
The floor ,, ,, = 116° C., ,, ,, ,, 116° C.

The other form of disinfector generally used in this country is that originally known as Washington-Lyon's, and is made by Manlove, Alliott & Co., Ltd., Nottingham. The leading points of difference between this and that made by Goddard & Massey are (1) that the boiler, except in the locomotive type, is usually kept distinct and separate from the disinfector, and (2) that the section is usually oval or round. The addition of the vacuum apparatus invented by Messrs. Alliott & Paton is a distinctive feature which is a great improvement. In Fig. 2 we show one of this firm's disinfectors of the old type, and in Fig. 3 the same fitted with the patent vacuum apparatus. Fig. 4 is a portable steam disinfector, for purifying wearing apparel and bedding in rural sanitary districts, with a circular chamber 5 feet long and 2½ feet diameter. The larger form shown in Fig. 5 has a chamber, 7 feet × 4 feet 2 inches × 2 feet 7 inches, with vacuum fittings.

With this class of apparatus, a special boiler is, of course,

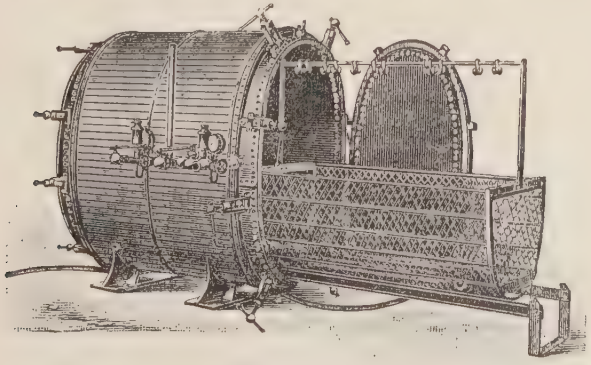


Fig. 2.—Lyon's disinfector (old type.)

not necessary when steam can otherwise be obtained. The pressure in the steam jacket is maintained at 32 lbs. per sq. in., but in the boiler it may be anything above this, as steam entering the jacket is automatically reduced to the required degree. In the chamber, the steam pressure is

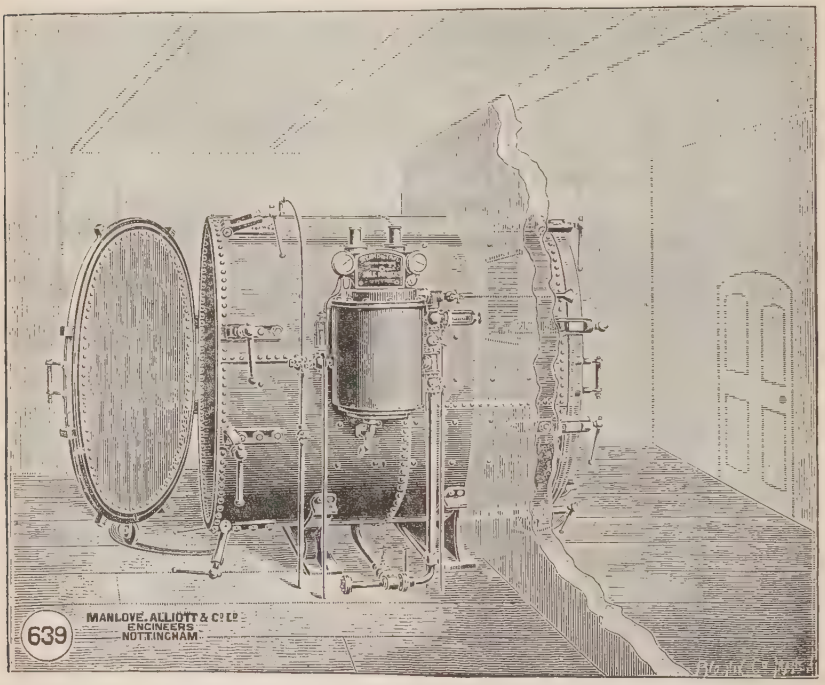


Fig. 3.—Manlove and Co.'s form of Lyon's disinfector fitted with vacuum apparatus.

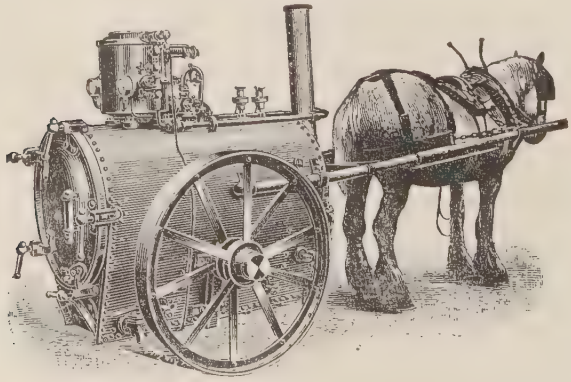


Fig. 4.--Portable steam disinfector.

maintained (also automatically) at 22 lbs. In apparatus not fitted with the vacuum arrangement, the pressures in jacket and chamber are usually 25 lbs. and 20 lbs. respectively. The higher pressure in the first case is found more convenient for the double purpose of air heating and extraction. This machine when fitted with the vacuum apparatus, may also be used as a dry heat disinfector, since hot air is admitted into a partial vacuum, which, in other words, is equivalent to working with hot air under pressure. The air is heated by passing it through pipes surrounded by steam at a constant temperature, and the danger of scorching is thereby obviated. The larger sizes of the machine are usually oval in section, and the smaller sizes round. This is presumably with the object of obtaining greater strength and durability, and in the oval form the largest articles can be disinfected without great expenditure of ground space. The separate boiler admits of ample inspection in the ordinary ways, and, if erected at the same

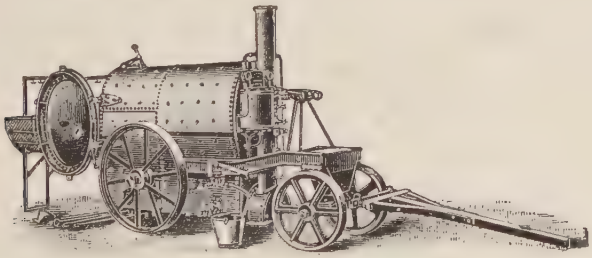


Fig. 5.—Larger form of portable steam disinfector with vacuum apparatus.

time as the disinfector, contains, in the most recent designs, arrangements for burning the whole of the gases exhausted from the disinfection chamber before passing them into the atmosphere. The best mode of working this apparatus under ordinary conditions is to admit a current of hot air for a few minutes, then obtain a vacuum, and break it with steam at 20 lbs. pressure. The steam having done its work of disinfection is discharged, a vacuum is again obtained, and a current of hot air completes the process. In the experiments on a medium size machine, details of which are given below, this course was not closely followed, as it

is not specially demanded unless the machine is very full, or the articles are bulky.

EXPERIMENTS ON A WASHINGTON-LYON'S PATENT STEAM DISINFECTOR WHEN FITTED WITH ALLIOTT & PATON'S PATENT VACUUM APPARATUS.

No. 1.—Charge, 4 mattresses and 4 pillows. Weight before disinfection = 109 lbs. 1 oz.

11.30 a.m.	doors closed.		
11.32 ,,	vacuum	16″	broken by hot air.
11.34½ ,,		0	
11.36½ ,,	,,	15″	,, ,,
11.39 ,,		0	
11.41 ,,	,,	15″	,, steam.
11.43 ,,		0	
11.47 ,,	steam	15″	maintained till 11.50 a.m.
11.52 ,,		0	
11.55 ,,	vacuum	11″	broken by hot air.
11.57 ,,		0	
11.58 ,,	vacuum	10″	,, ,,
12.0 noon		0	
12.2½ p.m.	,,	16″	,, ,,
12.4½ ,,		0	
12.6¾ ,,	,,	16″	circulation of hot air.
12.9 ,,	,,	10″	
12.12 ,,		0	doors opened.

Total time = 42 minutes.
Total increase in weight = 1 oz., or 0.05 per cent.

No. 2.—Two blankets fresh from the laundry wringing machine were next put in the disinfector. One blanket contained a large amount of soap, and it was noticeable that this one took far longer to dry than the one which was comparatively free from soap.

Before disinfection, the total weight was 15¾ lbs. After 50 minutes one blanket was nearly dry, and weighed 3 lbs. 3 ozs. The soapy blanket weighed 4 lbs. 2 ozs., and was perceptibly moist. The two, therefore, weighed 7 lbs. 5 ozs., or a *reduction* in weight of 54 per cent.

These blankets were then put back into the machine and completely dried, their total weight in that condition being about 6¾ lbs.

No. 3.—Subsequently, a charge of bedding was treated, consisting of blankets, pillows, sheets, etc.

The total weight before treatment was 29⅜ lbs.
,, after ,, 28 ,,
Total time 35 minutes.
Diminution in weight 1 lb. 6 ozs., or 4½ per cent.

In none of the foregoing experiments were the articles in any way damaged.

Dr. Whitelegge also made some experiments on this form of machine in 1889, when it was not fitted with the

vacuum apparatus. Permission has kindly been given to refer to them here, but space does not allow of their being dealt with as fully as they deserve :—

Steam was admitted to the jacket at 10 lbs., but the steam entered the chamber at a pressure of 5 lbs. only. A thermometer was placed inside one of the bulky articles to be treated, and so connected as to ring an electric bell outside when a temperature of about 105° C. was reached.

The door was closed at 12.35.

Steam was turned on at 12.37.

5 lbs. pressure in chamber at 12.38.

Bell rang 12.53½ (the bell ceased in 20 seconds upon intermitting the pressure immediately after this).

Steam was shut off at 12.56.

Door slightly opened to facilitate drying at 1.0.

Door opened wide, dry air inside, 1.5.

(*a*) Horse-hair pillow (2 lbs. 7½ ozs.) weighed 2 lbs. 9½ ozs., and was damp in centre, but dry on cooling. The electric thermometer at centre rang in 15 minutes, and corrected reading gave 106° C.

(*b*) A flock pillow (3 lbs. 6¾ ozs.) weighed 3 lbs. 9 ozs. (?), and was damp in centre, but dry on cooling. The corrected temperature was 104° C.

(*c*) Blue Saxony flannel $\frac{21\frac{1}{4}}{21} \times \frac{15}{15}$ afterwards measured $\frac{20\frac{3}{8}}{20\frac{6}{8}} \times \frac{14\frac{1}{2}}{14\frac{1}{2}}$ and was slightly yellow, but not felted.

(*d*) White unshrinkable flannel $\frac{21\frac{1}{4}}{21} \times \frac{15\frac{1}{16}}{15\frac{1}{16}}$ measured afterwards $\frac{20\frac{7}{8}}{21\frac{1}{8}} \times \frac{15\frac{9}{8}}{15\frac{8}{8}}$. This also was slightly yellow, but was not felted.

(*e*) Six samples of coloured silk, pleated, were unchanged, except that the dark green became wet and black. These had been placed near the door.

(*f*) Thick book (*Churchill's Directory*) on floor was cool inside. Thermometer placed uncovered in other parts of machine showed temperatures varying from 109° to 112° C.

A further experiment was then made on following lines :—

Door was shut at 1.21 p.m.

Steam admitted 1.22.

Full steam pressure attained in chamber (5 lbs.) 1.23.

Pressure was intermitted at 1.31.

Bell rang at 1.35.

(*a*) Two blankets, each folded into sixteen layers, laid one above the other on the wooden floor, were damp on removal, and dry on cooling.

The electric thermometer at centre—*i.e.*, with sixteen layers of cover—showed a corrected temperature of 109° C. The bell rang in 12 minutes.

Another experiment was made with low-pressure steam, with ½ lb. pressure in both chamber and jacket.

Door was closed at 2.17.

Steam at ½ lb. pressure in chamber at 2.20.

Bell rang at 2.37.

(*a*) Two blankets arranged as before were wet, but became immediately dry on shaking. The bell rang in 17 minutes, and the thermometer showed a temperature of 101° C.

(*b*) Horse-hair pillow came out steaming, and thermometer indicated 102° C. at centre.

(*c*) A flock pillow came out steaming, and the thermometer at centre indicated 100·5° C.

It is noteworthy in Dr. Whitelegge's experiments, that when steam at 5 lbs. pressure was used the thermometer at centre of blankets registered 109° C. in twelve minutes, and that when steam at ½ lb. pressure was used the thermometer, under apparently identical conditions, indicated only 101° C. after seventeen minutes, and also in the latter case pillows were taken out steaming. Although the types of disinfecting apparatus described are not absolutely the only ones used in this country, they probably include the majority of those erected in the past ten years.

A few years ago opinion seemed to be tending in favour of apparatus using steam at pressures of one or two pounds only, the benefit being one of first cost. Attention, however, was turned very quickly to the experiments of Dr. Miquel, published in the *Micrographie*, Nos. 3, 4, and 5, in 1895, wherein it was clearly demonstrated that at least four to five hours' exposure to saturated steam at 100° C. was essential to disinfection, even under laboratory conditions. Other experiments have also shown that disinfection by steam at such a low temperature is not absolutely trustworthy in all cases—such as smallpox, anthrax, and scarlet fever.

It is probable that in Koch's experiments with steam at 100° C. (page 31), and the disinfection thereby of anthrax spores, and even in the later ones of Dr. Klein (page 32), the spores in question were not maintained, under conditions satisfactory to their development, over a period of sufficient length. In short, steam at such a temperature does not necessarily destroy the vitality of the spore, but only tends to retard its development. This fact is brought out clearly by the experiments of Von Esmarch. The same

remarks apply, as stated above, to other spore-bearing organisms.

Dr. Delépine (*Journal of State Medicine*, December, 1897) has also recently maintained that as proteid substances are coagulated below 100 deg. C., a high temperature is not necessarily an essential for steam disinfection, and that obviously the pressure of the steam has no effect. He concludes from his own experiments that current steam when freed entirely from air, and properly used, is all that is necessary; but it ought to be noted that these experiments were made by the aid of very small sterilizing chambers. On the face of it, this may not appear to be a matter of importance, but it has been found in practice that it is a very real difficulty to obtain a large chamber filled with steam at a uniform temperature. In view of this fact, it is obvious that some margin of temperature, and consequently pressure, must be provided, even although steam at approximate atmospheric pressure must be used. This is rendered all the more necessary inasmuch as the natural barometric pressure varies from day to day, and therefore the temperature of the steam in the no-pressure machine may actually be below the standard temperature of 100° C.

These experiments have apparently so impressed this upon the better-informed manufacturers of low-pressure machines that they have introduced apparatus of a character generally similar to that of the low-pressure type, which work at a pressure varying from 8 lb. to 12 lb. above the atmosphere. It is possible that the pressure of 10 lb. may be sufficient under normal conditions to destroy all spore-bearing organisms, but in this respect perfectly satisfactory evidence is not yet forthcoming. The experiments, however, of Dr. Reid, of Stafford, show that the use of saturated steam at 20 lb. pressure is sufficient, and 2 lb. pressure is insufficient, to give absolute certainty to the process. To these arguments must be added the general statement that the low-pressure machine, by which is meant a machine using steam at a pressure not exceeding 3 lb., can be made in a very light and inexpensive manner. On the other hand, the low-pressure machine disinfects with certainty only in the cases of diseases produced by non-sporing organisms, and whose vitality is easily destroyed at this

temperature; whereas the apparatus using steam at 20 lb. pressure apparently provides with certainty for all contingencies, including small-pox, anthrax, and scarlet fever. The conclusion generally to be drawn from the above arguments would apparently be, that for small communities, such as those that are controlled by the Rural District and Parish Councils, where first cost is a matter of prime importance, the low-pressure machine would be excusable; but every County and Urban Council ought to have at least one of the high-pressure machines accessible for use in the event of an outbreak of a character that could not with certainty be dealt with by low-pressure steam.

In this way it would become possible for the Medical Officers of Health to differentiate between the two classes of disease, and to arrange for the high-pressure machines in the several districts to be used in times of emergency, *e.g.*, in small-pox outbreaks, whilst relying on the local low-pressure machines for typhoid and diphtheria cases.

Direction of the Steam Current.—Experiments in 1900 by Dr. Dunham, New York,[1] tended to show that in time boiling water, or saturated steam at atmospheric pressure, is capable of killing all pathogenic micro-organisms, and that the practical problem of sterilizing is to secure effective contact with all parts of the objects treated. He contended that provision must be made for the escape of the air contained in the apparatus, and that this escape should by preference take place at the bottom, because steam is very much lighter than air, the specific gravities being as 0 to 14·45, while air conducts heat very slowly. Thus it happens that unless the air contained in the apparatus is got rid of, it lies at the bottom, where it remains practically unaffected by the steam above. Hence the necessity, if it is desired that the full temperature shall be reached in every part of the apparatus in a reasonable time, that the steam should come in at the top, and should blow the air out before it at the bottom. The experiments were made in a cylinder six inches in diameter and nearly three feet high, through the sides of which four thermometers projected—one near the top, another near the bottom, and the other two at equal intervals between them, the time which it took

[1] *The Post Graduate*, May, 1900.

each of these thermometers to rise to 98 deg. Cent., or to the highest point to which it ever did rise, being noted. The difference of time, according to the positions of the inlet and the outlet, were very marked, the best results being obtained when the steam entered at the top and blew out at the bottom, and far away the worst when there was only one opening, and that one at the top. In this case the temperature at the bottom never rose anywhere near the boiling point, although the experiment was continued for a long time. In another series in which the cylinder was filled with cotton, and thus represented more accurately the conditions existing in ordinary practice, the direction of the current of steam, so long as there was a current, was found to exert much less influence. In fact, it would appear that when the cylinder was stuffed with cotton, so that there was no internal circulation, the steam passed from end to end in a compact column, and it did not much matter which way it went. The same lack of circulation, however, had a disastrous effect when the attempt was made to do with only one opening; for whether that was placed at the top or at the bottom, the steam failed to raise the temperature evenly; and in the case where the opening was at the top alone there was a complete failure to do more than heat the very uppermost layers, the two lower thermometers remaining unmoved, notwithstanding that the one at the top was almost at a boiling temperature. The moral of these experiments, and of others dealing with high pressure sterilizers fitted with "ejectors," is that in whatever form steam is used, unless there is a complete blow through, there is no security that the heat will reach every part of the contents.

Freedom from Air.—Heidenreich proved in 1887 (*Zeits. f. Wiss. Mikrosk.*, Bd. 4) that steam containing air effected heating much less rapidly than pure steam. The fact was forcibly recalled by Wolf Defries in a paper at the Sanitary Congress at Bradford in 1903, wherein he described an ingenious apparatus he had devised for testing steam. It consisted of a syphon with two nearly equal legs dipping into vessels of water. The steam is at intervals forced into the syphon through a cock which is then closed. The steam at once condenses, drawing the water up, but as long as a bubble of air remains the syphon will not work. As

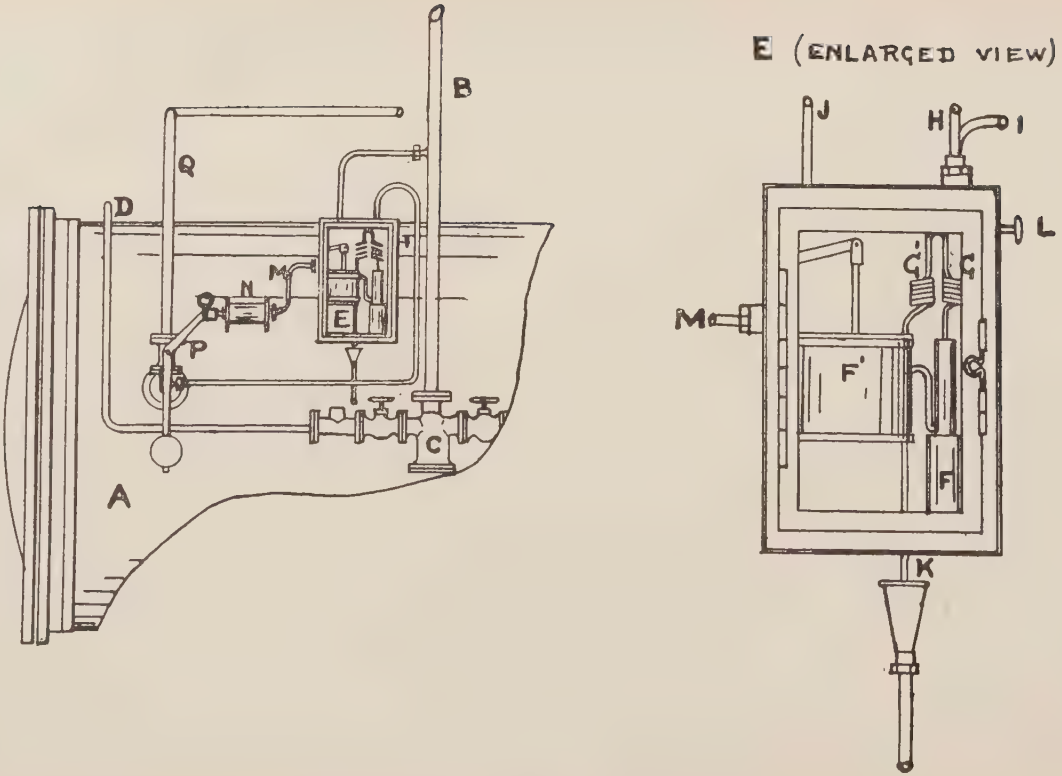


Fig. 6.—Defries' Syphon Air Controller.

soon as freedom from air is attained, the syphon becomes completely filled and commences working, drawing the water over into the lower vessel. The weight of water moves the lever of an indicator, or in an automatic form of the apparatus it closes or opens the valves admitting the steam to the disinfector and to a pressure-recording gauge.

THE THRESH DISINFECTOR.—Forms of apparatus working under pressure have several disadvantages, both in initial cost, expenses of working, leakage, and a certain amount of danger unless manipulated by skilled hands. The Thresh machine obviates these difficulties by employing a continuous

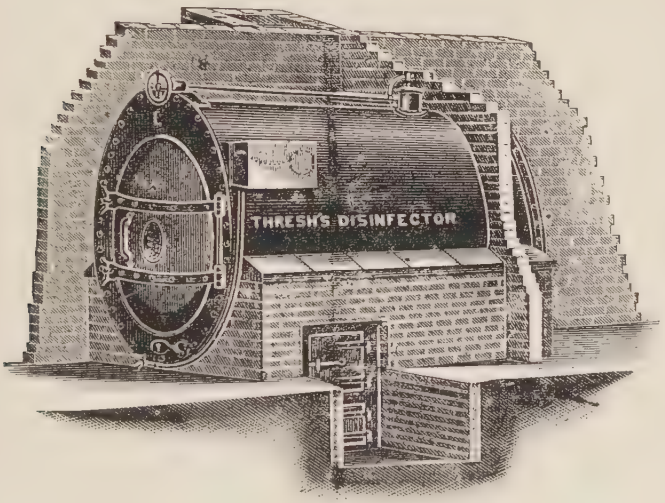


Fig. 7.—The Thresh Disinfector.

current of steam, which is also maintained above 100 deg. C. at atmospheric pressure by dissolving in the water in the boiler a definite quantity of potassium carbonate.

The apparatus consists of a horizontal boiler with double walls forming a jacket round the disinfecting chamber; this jacket, which contains the calcium chloride solution, communicates by a three-way cock to the inner chamber or to a waste flue. The disinfecting chamber has doors at one or each end, and is in open communication with the flue. To start the disinfector the doors are closed, the potass. carbonate solution is heated to boiling and the steam passes through the inner chamber to the waste pipe, no pressure being

obtained. After the disinfection the three-way cock is turned so as to pass the steam direct into the flue, and heated air is drawn through the disinfecting chamber to prevent condensation and drive out the steam. The boiler is automatically fed with ordinary water to a constant level, so that the strength of the solution remains unaltered.

In the *Lancet,* January 11th, 1896, details of an elaborate series of trials of this disinfector are given. The maximum temperature obtained in the centre of the disinfecting chamber was found to be 104° to 105° C., a bell recording thermometer in the centre of eight folds of blanket registering 100° C. in eight minutes after admittance of the steam (but this would depend on the time that the apparatus had been previously heated), and by means of recording thermometers placed in different positions the distribution of the heat was found to be very uniform.

The bacteriological results obtained were satisfactory. Swabs and test tubes plugged with cotton-wool, infected with diphtheria, typhoid, cholera, anthrax spores, and the pus organism (staph. pyogenes aureus), buried in eight and sixteen folds of blanket and between a folded bed mattress, were all rendered innocuous after 30 minutes' steaming and 30 minutes' drying with hot air; anthrax spores were also destroyed when placed in the middle of a book of 800 pages. The resistant power of the spores was tested, and they showed vigorous growth after being "heated to 100° C. for 15 minutes." Elaborate precautions were taken with the sub-cultures, but the time of incubation is unfortunately not stated.

The time required for each charge was found to be 1 hour, 30 minutes' steaming and 30 minutes' drying, and 7 hours' continuous work used 1 cwt. of coal. When taken out of the disinfecting chamber and shaken, articles were found to be quite dry, with the exception of a mattress, which gained 4 oz., and pieces of mackintosh rubber, horsehair, and tobacco were apparently uninjured by the whole process.

Fraser (*J. State Med.*, January, 1896) also reports favourably on the Thresh disinfector, finding, in agreement with the *Lancet* report, that anthrax spores protected by blankets were destroyed by 30 minutes steaming and 30 minutes drying; and further, the resistant spores of the hay bacillus

(B. subtilis) were killed. He suggests that passing hot air through the disinfecting chamber after the steaming, is only necessary in the case of bulky goods, light articles being found to be quite dry when removed directly after steaming and shaken two or three times in the open air, although as he remarks, the disinfection is perhaps aided by the subsequent drying at the high temperature.

TYPES OF DISINFECTORS USED ON THE CONTINENT.

Several of these are now also in use in this country.

1. AUSTRIA—THURSFIELD'S APPARATUS.—This form, introduced by Mr. Thursfield, of Gumpoldskirchen, near Vienna, has been largely used by the Austrian Government, and has lately been adopted by the British Government in special cases. It works at a few pounds pressure, the steam passing from a jacket downwards through the central disinfecting chamber, and escaping through holes at the bottom to a waste pipe. The following is a record of

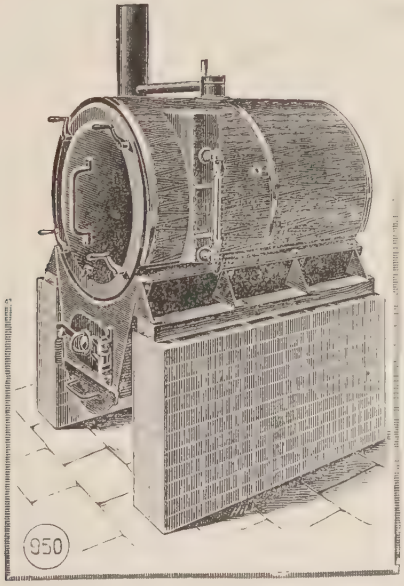


Fig. 8.—Thursfield low-pressure disinfector.

trials recently made by the author with this apparatus.

The disinfector was of the stationary type (Fig. 8) fitted with double doors, and having a chimney at the side, so

that it is possible to erect a wall between the infected and disinfected ends of the apparatus. The disinfector used was tubular in form, and had a length of 1·10 metres (43in.) and a diameter of 0·70 metres (27in.) The quantity of coal consumed per hour is about 10 lb., and 17 gallons of water are required to fill the boiler before starting work. Three experiments were conducted.

(*a*) The furnace was lighted at 10.40 a.m., and a thick piece of blanketing, measuring 35ft. long and 10ft. wide, and weighing 58 lb., was folded in 64 folds, and then inserted in the disinfector. Within the folds of this blanket a thermometer set to ring at 100° C. with 32 folds on each side, was placed; also a box containing body lice, some old sacking, a shirt from the workhouse containing lice and their eggs, and paper strips impregnated with active cultures of the following organisms, and placed in envelopes:—

1. Anthrax and spores in the thirty-second fold.
2. Staphylococcus pyogenes aureus in the sixteenth fold from bottom.
3. Bacillus coli communis in the eighth fold from bottom.

Two self-registering thermometers, which were subsequently standardised, were also placed at the base, and in the centre of the blanket. I found that the water began to boil at 11.25 a.m., and that at 11.34 a.m. the thermometer placed in the steam outlet registered 100° C., showing that the disinfector was then filled with steam. At 11.36 a.m. the bell of the automatic thermometer rang, indicating that a temperature of 100° C. was reached within the central fold of the blanket. The steam enters on to the top of the goods as soon as the water begins to boil, and passes down through them, escaping through holes placed in the bottom of the chamber to an exit pipe which communicates with the chimney of the furnace. At 12.19 p.m., or 45 minutes after steam had been formed, water was added to the boiler, and the steam within the disinfector condensed. The doors were then opened, and the goods, on shaking in the air, were found to quickly lose any damp feel, and were practically dry within a minute from leaving the apparatus.

The thermometer at the base registered 102·2° C., and

the one in the folds of the blanket 101° C. The lice in the box were dead, and the eggs, placed under suitable conditions for hatching, did not develop. The paper strips impregnated with the organisms were transferred to sterile tubes, and fresh cultures taken from them. These cultures showed no signs of the growth of the several organisms after being kept in the incubator under favourable conditions for five days.

The control tubes showed that the cultures were active; but it will be noticed that the experiments were discontinued at the end of five days, so that the objections since raised as to the arrested vitality of anthrax spores under these circumstances apply also to these results. On the fifth day a micrococcus appeared in the B. coli tube, which I regarded as adventitious, as no bacilli accompanied its development.

(*b*) In the second experiment holes at the base were first covered with sacking, and three stout boards made of wool and paper were inserted in the apparatus with a thermometer and a paper impregnated with an active anthrax culture embedded in the central board.

Several filter press mats, weighing 20 lb., and folded, were placed above the woollen boards, and papers soaked in (1) anthrax culture, (2) B. coli culture, and (3) Staph. pyogenes aureus culture, were placed with the pyrometer in the centre of the folded sacking. A London Post Office Directory with a self-registering thermometer imbedded in its centre, the book being then carefully and tightly bound with string, was also included in this test.

The experiment was commenced by screwing on the doors at 3.5 p.m., the fire being already up. At 3.20 p.m. the thermometer in the steam exit tube read 100° C., and at 3.21 the bell rang from the pyrometer placed in the centre of the sacking. At 4.6 p.m. the disinfector was cooled by adding water, and the doors opened. Both thermometers within the book and between the felt boards registered 102° C. The four bacteriological tests gave negative results after suitable sub-cultures had been taken.

(*c*) In a third experiment various samples of coloured silk, wool, and printed cotton goods were placed in the machine, and steam allowed to act upon them for ten minutes. At the end of this time they were removed, and

the colours compared with test samples which had not been so treated. In no case was any appreciable difference in the colour or texture of the various articles detected.

It would seem, therefore, that apparatus of this type can be safely relied upon to effect disinfection when the time of exposure to the steam is not less than forty-five minutes; and that, as already pointed out, high-pressure machines need only be used in exceptional cases, and when dealing with diseases produced by unknown or very resistant organisms.

Figs. 9 and 10 show other Thursfield types; the former,

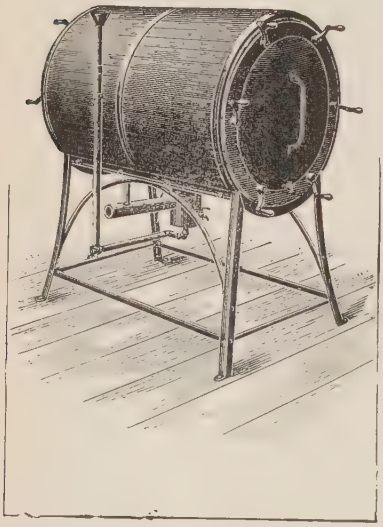


Fig. 9.—Thursfield Disinfector for separate steam supply.

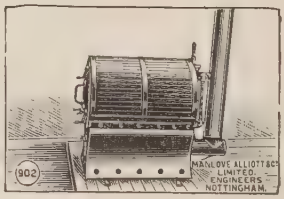


Fig. 10.—Small gas-heated Thursfield apparatus.

with two doors, is arranged to take steam from an existing boiler; the latter is a smaller form heated by gas.

2. France—The Equifex Stove.—A common type of apparatus in France is that made by Geneste, Herscher & Co., of Paris.[1] This machine is externally not unlike those of Washington-Lyon, although its construction is materially different, inasmuch as there exists no steam jacket, and only comparatively low-pressure steam is employed. It is made

[1] In London—J. Defries and Sons, 147 Houndsditch, E.C.

in several sizes and types, which may be briefly described as follows:—

(1) Is a fixed machine working with steam at from 7 lbs. to 10 lbs. per square inch; consequently the maximum temperature to which the infected articles are exposed is from 110° to 115.5° C. The large size is commonly 6 ft. diameter and 13 ft. 6in. long, and contains two sets of steam-pipe coils. Each set consists of eleven pipes running the whole length of the machine, one being placed at the top, the other at the bottom of the chamber, the object of the arrangement being to facilitate drying and to prevent condensation. The air escapes through a pipe at the bottom of the disinfector pending the admission of steam, with which the disinfecting process is commenced. When the pressure has reached 7 to 10 lbs., the steam is exhausted and a fresh quantity admitted. In this way the inventors claim that sufficient penetration is secured without the aid of steam at a higher pressure, and also that it is only necessary that steam at 10 lbs. be actually in contact with the goods for not less than fifteen to seventeen minutes, in addition to the time taken in filling and exhausting the chamber, which should be done not less than three times during the operation. Before the goods are taken out it is recommended that they be left in the closed machine for some time to dry, although the precise time taken by this process is not clear.

(2) Is a machine working at from 2 lbs. to 5 lbs. pressure with current steam, and the temperature to which the goods are exposed does not exceed 103° to 105·5° C. The steam enters the chamber at the top and is extracted at the bottom, to more effectually drive out the air (see page 54), but the pressure is rather too low to make its relaxation and renewal of much benefit to penetration. The steam is only nominally "current," because the outlet is governed by a modified form of reducing valve. A feature of the apparatus is that the two doors are so interlocked that it is impossible to have both open at the same time, but otherwise the arrangements in this type are similar to those in the other. In Fig. 11 we give an illustration of an Equifex horizontal stove working with confined steam.

"The disinfecting chamber, A, is a wrought-iron cylinder without jacket or other means of superheating the steam, but lagged

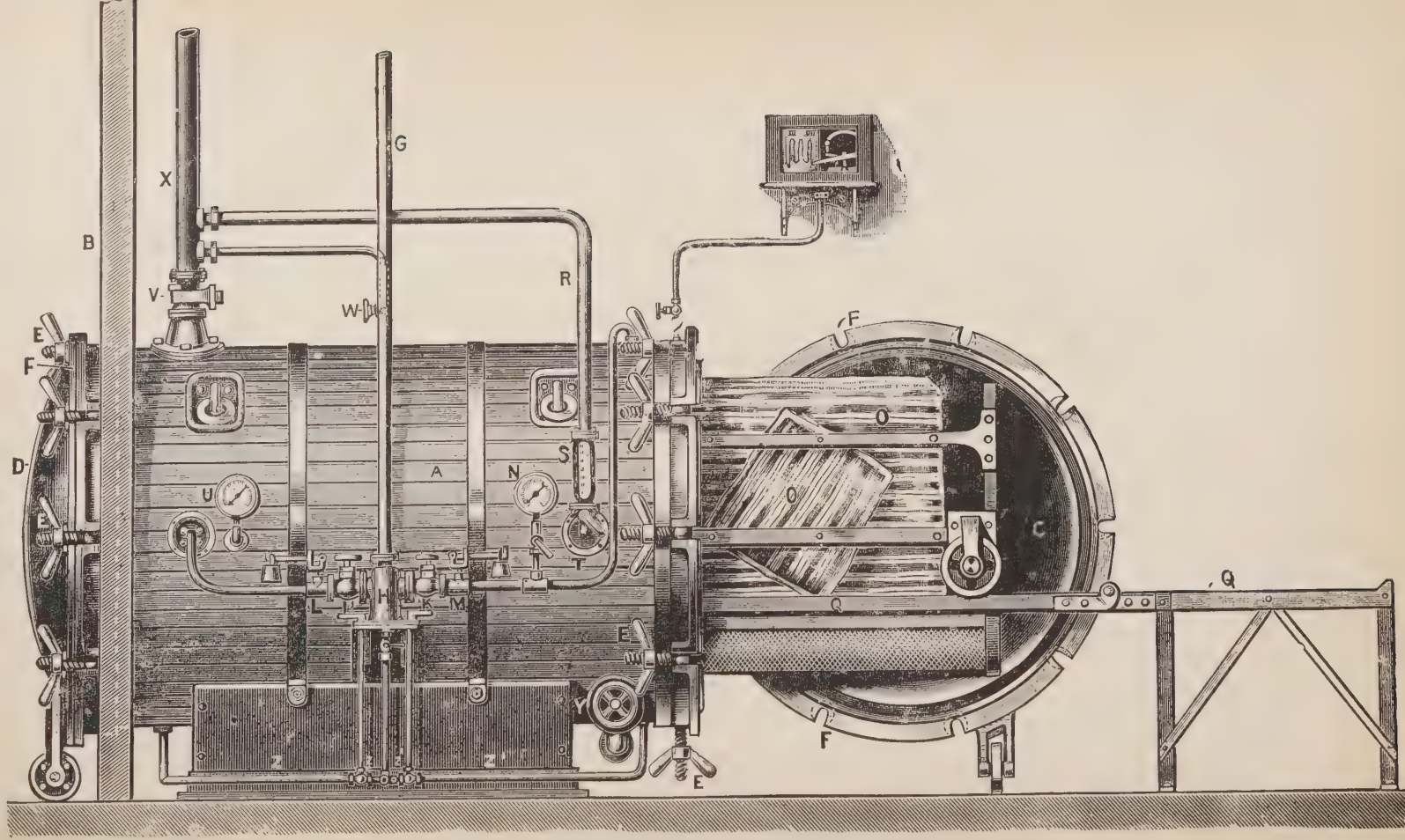


Fig. 11.—Equifex Horizontal Steam Disinfecting Stove.

with wood and coated with a non-conducting composition. The stove usually passes through a partition, B, to separate the infected objects from the disinfected. The doors, C, D, are fitted with an arrangement making it impossible for both to open at the same time, and are secured by nuts, E, locking into solid steel recesses, F, on the door. A row of steam tubes runs longitudinally inside the stove for warming the stove before and during disinfections, and for heating the air which is used in the subsequent drying of thick objects. The steam is led to the stove by a pipe, G, from the boiler, and, after traversing a separator, H, passes through the reducing valve, I, K, and safety valves, L, M, to the stoves and tubes respectively. When the desired pressure is reached in the tubes, as shown by the gauge, N, steam begins to escape through the safety valve, M, and the attendant then regulates the pressure by the reducing valve, K. The stove, having thus been warmed, is charged with the objects, O, to be disinfected, which are loaded in the ordinary way on to a wheeled carriage, P, running on rails within the stove, and on hinged rails, Q, outside. The door is then closed, and locked with the safety nuts, E, and the valve, I, is opened, allowing steam to pass through the safety valve L, into the body of the stove. The steam enters the stove through an internal sparge-pipe fitted longitudinally inside it towards the top, and furnished throughout its length with a screen to assist in the thorough projection of the steam to all parts of the stove. The steam is at first allowed to escape through the air discharge pipe, R, and carries with it the air from the stove. The discharge pipe, R, is fitted with a thermometer, S. When the air is ejected, the mercury will rapidly rise to 90·5° to 96° C., at which point the valve, T, controlling the pipe, R, is closed. The steam continues to enter the stove through the valve, I, till it reaches a pressure of 10 lbs. per square inch, as marked on the gauge, U, when it escapes through the safety valve, L, until the attendant has regulated the pressure by the reducing valve, I. A film of water is formed throughout the pores of the object under a pressure just sufficient to keep it from evaporating. Advantage is taken of this fact to get rid of the air secreted originally in the pores of the object, by shutting off steam occasionally (say every five minutes) by means of the valve, I, and opening the sluice valve, V. The sudden reduction of pressure so effected causes a sudden re-evaporation of the condensed steam in the objects; so what was water in the pores expands into steam of some sixteen hundred times its volume, sweeping out before it the air from the pores. To assist this process the stove is fitted with a pneumatic exhaust, operated without any moving parts by the steam pressure. For this purpose a jet of steam is allowed, by means of the valve, W, to pass up an aspirator or ejector fitted in the steam discharge pipe, X, so automatically sucking out both the steam and the air ejected from the pores, and producing a partial vacuum under which the vaporisation of the steam and the ejection of the air is completed. With

objects of ordinary thickness disinfection is complete in fifteen to seventeen minutes. Steam is then let off as before; and on the door being opened, all objects such as blankets, clothes, etc., are taken out and shaken, when they will be found to be perfectly dry. Mattresses and thicker objects are replaced in the stove for five minutes for the aspirator to withdraw the steam."

3. Denmark—Reck's Disinfector.—This apparatus, by A. B. Reck, of Copenhagen, was introduced in 1888. It works with a constant current of saturated steam at 102°, or if desired 110° C., at pressures of 1½ to 7 lbs. The steam enters at the top of the chamber and escapes below through a perforated valve. After a certain time, a water spray is injected in the upper part over a protecting screen and condenses the steam, so that the doors can be at once opened and the goods removed to a separate drying closet heated

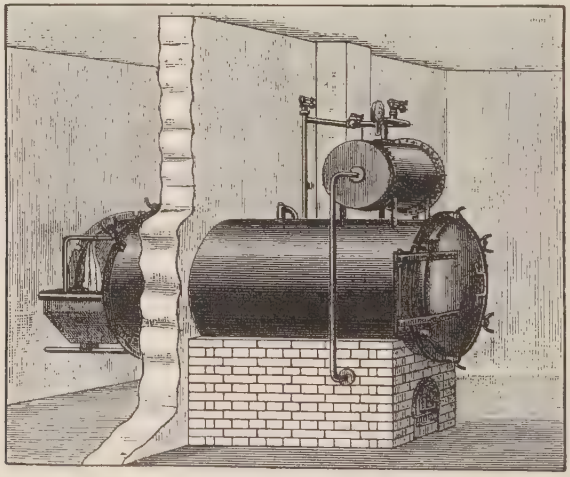


Fig. 12.—Reck's Disinfector.

by the waste steam. The disinfector was thus filled and emptied twice in an hour. Dr. Reid has reported very favourably to the Staffordshire County Council on his tests of this apparatus.

A special arrangement has been introduced which allows the boiler for the disinfector to be placed directly under the same, and further prevents "priming," or the carrying over of particles of water along with the steam into the disinfecting chamber. It consists of a cylindrical steam

chest placed above the boiler, so that the steam is drawn off above the area of splashing. By this arrangement the cylinder acts as a hot water reservoir for the boiler, which thus only requires feeding in the interval between two succeeding processes, and is capable of generating steam so fast that five to seven minutes will suffice to heat up the disinfector to a temperature of 100° C.

These disinfectors are made both for inside and outside drying. For the former (Fig. 14), the disinfector is surrounded with a water-jacket. During the steaming process the water in the jacket is heated to the same temperature as the interior, and then air is allowed to pass through the disinfector. On account of the great capacity of water for storing heat, the water-jacket gives off heat enough for drying the articles completely before they are taken out. For outside drying, if required, a drying closet, heated by exhaust steam condensed in steam radiators with large surfaces, is provided (Fig. 13).

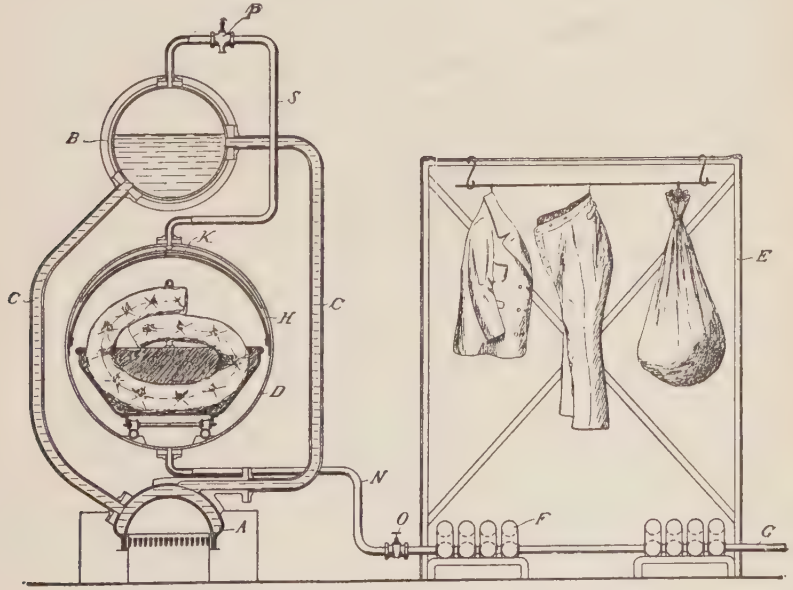
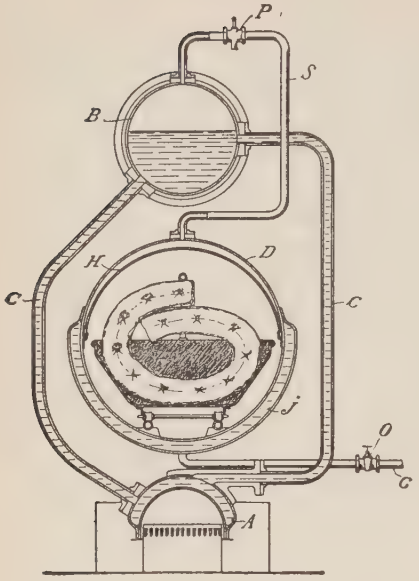


Fig. 13. Reck's Disinfector for outside drying.

A, Saddle boiler. *B*, Steam drum. *C*, Circulating pipes. *D*, Disinfecting chamber. *E*, Drying closet. *F*, Steam coil. *G*, Open exit-pipe. *K*, Screen for breaking the current of the steam or water. *N*, Exhaust pipe for disinfecting chamber. *O*, Perforated valve. *P*, Automatic pressure regulator. *S*, Steam pipe from drum to disinfector.



A, Saddle boiler.
B, Steam drum.
C, Circulating pipes.
D, Disinfecting chamber.
G, Open exit pipe.
H, Screen for breaking the current of the steam.
J, Water jacket.
O, Perforated valve.
P, Automatic pressure regulator.
S, Steam pipe from drum to disinfecting chamber.

Fig. 14. Reck's Disinfector for inside drying.

In the report of a committee appointed by the Director General of French hospitals to investigate steam stoves the Reck apparatus was pronounced to be satisfactory in working, all the articles placed in it reached in a very short time, and kept during the whole operation, the temperature decided on, namely 105·5° C., and the machine had the advantage of not requiring any official test for safety, as the hydraulic valve for regulating the pressure was perfectly efficient. Experiments were made with diphtheritic membranes and dried tubercular sputa; these were found to be sterilized, and even anthrax spores are said to have been destroyed by the full time of disinfection. A very severe test was made as to the damage that might be sustained by articles in apparatus by various makers. In the Reck a number of different materials were subjected to a quarter of an hour's disinfection on 30 successive days, that is 30 times altogether. Cotton, wool, wood fibre and horsehair were practically unaffected by the Reck disinfection, a result which was superior to that obtained with other disinfectors used in the French hospitals. Although the price, and the provision of a convenient variety of sizes, are conditions secondary to efficiency, they mention these as advantages of this make of apparatus. Dr. Corney reported from Fiji in August, 1898,

that in disinfecting blankets he found it possible to pass 12 charges through the instrument in 8½ consecutive hours, giving 30 minutes steaming at 102° C. and 1½ lbs. pressure, exclusive of the time for getting up steam to begin with, and no infection spread beyond the quarantine station.

The form for inside drying is cheaper, but that for drying outside is quicker in working and has a larger capacity per hour.

4. Germany—Schimmel's and Budenberg's Apparatus. A disinfecting apparatus largely used in Germany is that made by Oscar Schimmel, of Chemnitz. There is nothing very striking in its design, and probably the explanation of its extensive use may be found in the fact that it was one of the first to be placed on the market. The claims made are, broadly speaking, three. First, the clothes are warmed by hot air to a temperature of 60° C.; secondly, they are steamed by current steam at atmospheric pressure; and lastly, they are partially dried, and aired again by warm air. No pretence is made that the articles come out perfectly dry, or that the process is a rapid one, but it is claimed that articles which are not too bulky are disinfected, and also that the first cost of the apparatus is moderate. Fig. 16 shows a small vertical type with steam-generating apparatus and fire beneath. Steam rises round the chamber in which the clothes are situated, and enters at the top and leaves at the bottom, while condensed steam returns to the boiling apparatus. Great care would have to be exercised to see that water never ran short in the domed bottom, for it is very small in quantity, and would need frequent replenishing by hand through the funnel. When a charge has been disinfected, the fire has to be drawn in order that steam may be prevented from passing into the chamber. To obtain air circulation, a small door is removed in the crown, and, the exhaust pipe being also open, a certain air circulation is obtained owing to the heat retained in the clothing and walls of the chamber.

In the larger size shown in Fig. 15, which is oval in section, more elaborate arrangements are provided for air heating, etc., and steam has to be obtained from a separate boiler. The gilled pipes at the bottom are filled with steam at boiler pressure, and thus to some extent they check

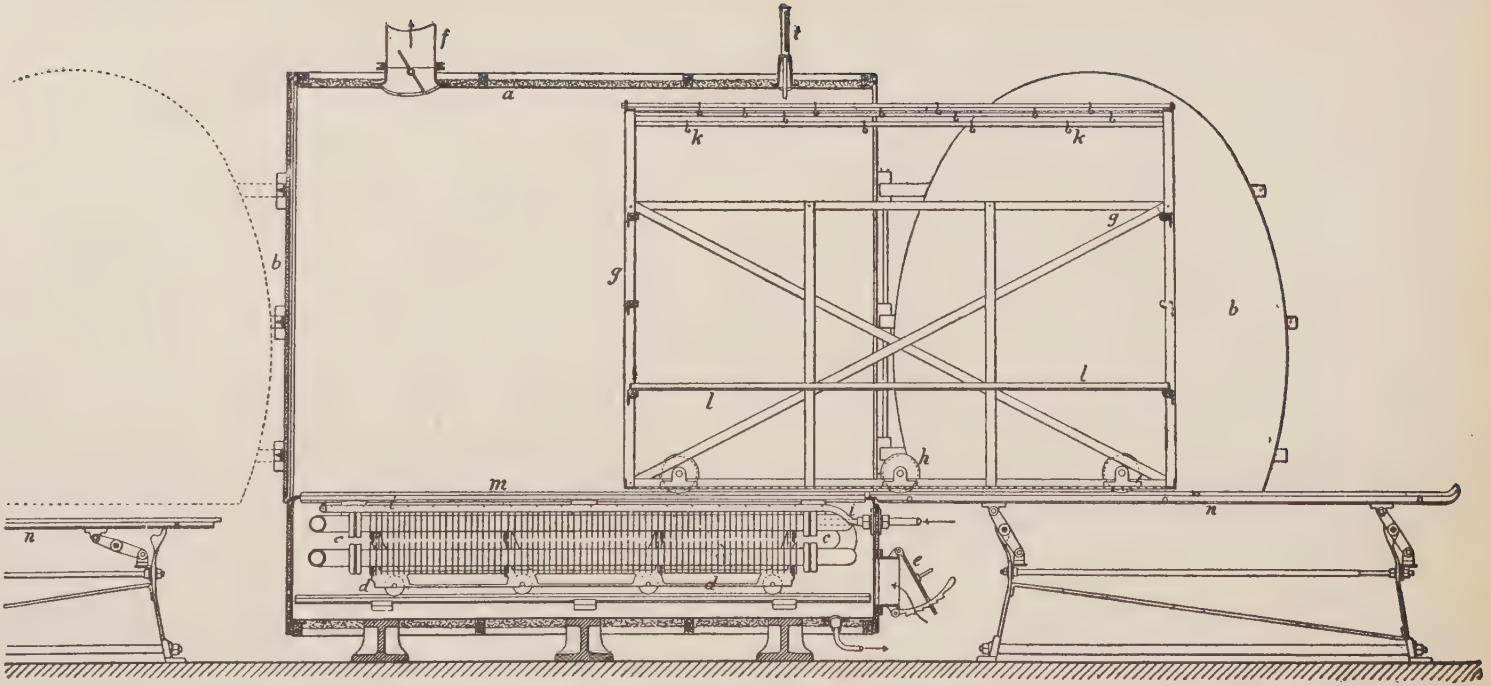


Fig. 15.—Schimmel's large steam disinfector.

condensation in the chamber when steam at atmospheric pressure is admitted. Air circulation is again obtained entirely by the crude method of opening a small door at the bottom of the chamber close to the gill pipes, and allowing it to rise and escape at the top by the exhaust pipe. Machines of this type have been at work in Berlin for about ten years. In the larger apparatus it is usual to admit current steam to the chamber at about $1\frac{1}{4}$ lbs. pressure. It is necessary when working the apparatus, first to warm it up by hot air for not less than thirty minutes, and then, after putting in the goods,

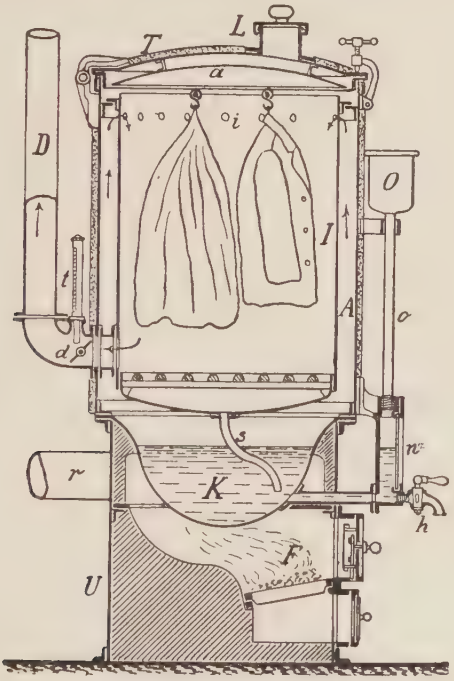


Fig. 16.—Schimmel's vertical steam disinfector.

to again warm them for thirty minutes or thereabouts. Steaming is said to take about thirty minutes (although this must surely depend largely on the articles being treated), and the final drying occupies another fifteen minutes. The whole process, including loading and unloading the truck, should therefore, mean an expenditure of time amounting to nearly two hours; and, even when taken out, the articles are supposed to undergo a further process in an ordinary drying closet.

The apparatus of W. Budenberg, of Dortmund, works at about 3 lbs. pressure, and is very similar to that of Geneste Herscher. It has been carefully studied by Dr. Hahn.[1]

In M. Henneberg's apparatus, made by Rietschel & Henneberg, Berlin, hot air is first admitted from above to heat the articles to be disinfected, and then steam, the latter being directed upwards by the guard over the steam inlet, and both the hot air and steam find their outlet below. The chamber has no double jacket, but is framed in non-conducting material. Two types are made, one working at one-twentieth atmosphere (about $\frac{3}{4}$ lb.), and the other at one-fifth atmosphere (about 3 lb.) steam pressure.

Van Overbeek de Mayer's disinfector is one of the simpler forms of apparatus for use with steam at atmospheric pressure. It is said to work well and to have the additional advantage of being cheaper and less complicated in construction than some others. The chamber is provided with a jacket, and steam is generated first in the jacket-boiler and passes thence into the interior of the chamber through an opening in the top. Judging by the experiments that have been made, penetration appears to be little less rapid than it is at a higher temperature and pressure. Drying of the disinfected articles afterwards is provided for by means of a current of hot air, which can be passed through the chamber after the steam has been shut off, but it is rarely found necessary.

Dr. H. Rohrbeck's disinfecting apparatus is constructed on a somewhat different principle and seems to be an excellent stove. Steam is made to pass over a cooling surface before it is allowed to enter the disinfecting chamber, and by this means it becomes thoroughly saturated first, and afterwards the steam in the disinfecting chamber is condensed, and consequently it imparts its latent heat to the objects, thereby producing a vacuum, and thus the air is sucked out of their interior and the efficiency of the disinfecting process greatly increased. When steam is again allowed to enter it readily forces its way into the interior of the objects and completes their disinfection. After the conclusion of the process the disinfecting chamber acts as a drying oven.

[1] *Deutsch. Medic. Wochensch.*, 1890, No. 12.

United States.—In the United States the apparatus of Geo. V. M'Lautlin & Co., of Boston, is used to some extent, as is also that of Washington-Lyon. M'Lautlin's machine bears a very close resemblance to Geneste Herscher's apparatus, the only appreciable difference being that it is built in an apparently more substantial manner to enable it to work with steam at a pressure exceeding 10 lbs.

Doty's disinfector[1] is fitted with his special vacuum apparatus. A steam exhauster is connected with both the chamber and the jacket, and the first step in the process of disinfection consists in creating a vacuum of one and a half atmospheres, and this with Doty's arrangement can be done in one minute. The air having thus been exhausted from the chamber and its contents, steam is admitted, and the temperature rises in three or four minutes to 110° or 115° C. At the expiration of 15 minutes the steam exhauster is again used to secure the previous degree of vacuum. This removes the steam from chamber and contents, and then a fresh air inlet is opened, and a current of air drawn through for eight or 10 minutes, so that goods are taken out completely dried. The time occupied in disinfecting is reduced by one-half, thorough penetration is ensured, and goods are but little affected. The utilization of the fresh air inlet secures the thorough drying of materials so that clothing is immediately ready for use. The efficacy of the method was tested by registering thermometers in the interior of packages of paper, and by bacteriological cultures similarly protected. The results are reported to have been eminently satisfactory. A similar apparatus is Francis's U.S. patent 704,182 of 1902.

Generally speaking, disinfecting apparatus on the Continent is built with rather a different object in view to that which obtains in this country. It is not regarded as essential for the clothes to come out absolutely dry; and if they have to be dried by some other means after treatment, that is not considered prejudicial to the machine. Time, also, is not valued to the same extent as it is with us, whereas first cost is a matter of the greatest importance. As a consequence, a cheaper machine is produced, which disinfects at the expense of wetting the goods after a more prolonged exposure. These conditions do not obtain

[1] *Amer. J. of Med. Science*, August, 1898.

generally in this country, for frequently, owing largely to recent regulations, the whole of the clothing and bedding of a family have to be disinfected and returned ready for use within one or two hours, whilst the family is housed at the public expense pending the chemical disinfection of their own room. The public sentiment is also in favour of purchasing things of the most durable nature, in spite of the fact that their first cost may be greater. Lastly, the use of low-pressure steam is not largely favoured, because very bulky articles, such as bales, cannot be disinfected in machines using it; whereas, high-pressure machines can not only deal with the bulkiest articles, but can always, if desirable, be used with low-pressure steam with equal efficiency.

Examples of earlier and later patents for supplementing the use of steam by chemical disinfectants are the following: Fryer & Alliott (No. 1,565, 1877) place sewage pails in an air-tight vessel, exhaust the air, then let in "steam, hot air, sulphurous acid, chlorine, phenol vapour, or other volatile disinfectant." The process is also stated to be suitable for the disinfection of wearing apparel, bedding, etc. But the disinfectant should not be corrosive, and the gases drawn off at first would have to be passed into a furnace or be chemically dealt with. W. Defries' patent 3137, of 1902, is a special chamber which, after the steam has acted for a certain time, is exhausted and then filled with disinfectant vapour, and afterwards subjected to sudden exhaustions to dry the articles. Fournier (patent 10,348, 1902) has a chamber using steam and "formacétous" (acetonized formaldehyde).

Public Installations.

To a certain extent each case has to be treated on its merits and the building must be adapted to its environments, as well as the sheds for the infected and disinfected vans or hand carts.

The main feature of a disinfector house is that there shall be two rooms; one permanently kept for infected, and the for disinfected goods. The machine is built in the wall dividing the two rooms, and is fitted with two doors, one door opening into each room. These doors should never

be open at the same time, and there should be no direct inter-communication whatever. Two men should be provided to work the apparatus, one of whom should have his duties confined to the infected side, and the other to the disinfected side of the apparatus. Generally, one man is told off to look after the infected side, where the boiler and things that require attention are placed, and he signals or shouts to some man engaged on other work when goods have to be moved from the machine into the disinfected room. The passages, entrances, and exits of the station must be so arranged that goods after disinfection need never be carried over the same ground, or through the same doorway, as the infected goods: this is a necessity which is sometimes neglected. An incinerator is no essential part of

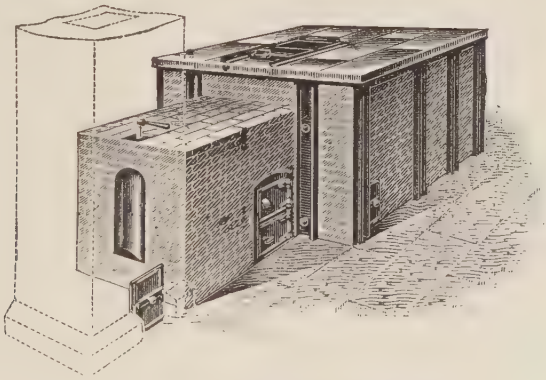


Fig. 17.—Dr. Sergeant's incinerator.

the disinfection, but is, nevertheless, sometimes put on the same site for the purpose of destroying by fire bedding or clothing that is not worth disinfecting. For instance, it sometimes happens that the mattresses of cholera patients are purposely of the commonest description, and only fit to burn. They can only be burned in very carefully constructed furnaces, fitted with a secondary fire to destroy the objectionable products of combustion; otherwise, the process might become a nuisance and danger to the neighbours. They are also useful for getting rid of condemned meat, offal, excreta, etc. A figure of Dr. Sergeant's incinerator is shown in Fig. 17. The same chimney may be used for both the disinfector boiler and incinerator, but otherwise the two departments are kept distinct. The minor points to be

attended to in the building for a disinfector require also some care. The floor should be of some smooth, hard material, such as cement, laid with a fall towards a drain; and arrangements should be provided for swilling out the two rooms very thoroughly by fixing a small hose to taps in either room. All internal angles should be rounded, so as to permit of ready cleansing; and slate and iron should be used where possible in preference to wood for the racks and fittings. Good washing accommodation and w.c. should also be provided for the attendant, and special overalls should be given him for wear whenever at work in the building. These overalls must always be disinfected before allowing them to go to the laundry. Considerable attention should be paid to the ventilation of both rooms, as in summer the radiated heat from the boiler and machine is apt to be oppressive. The lighting should also be ample and well diffused, for this encourages cleanliness.

United States.—For the Marine Hospital Service of the U.S. Government at the modern stations, plant has been provided for disinfecting by heat, by fumes, and by solutions. The arrangements have been described by W. H. Francis of Philadelphia.[1] The disinfectors are two rectangular steam-jacketed chambers 16 feet long, with steam-tight doors opening at each end. The chambers are constructed of an inner and outer steel shell, $2\frac{1}{2}$ inches apart, cast-iron end frames, intermediate truss bands, and of screw stay-bolt construction. The doors have concave steel plates riveted to cast angle-frames fitted with heavy rubber gaskets; they are handled by convenient cranes, and drawn tight by drop-gorged steel eye-bolts, swinging in and out of slots in the door frames. The chambers, therefore, act as drying ovens, the articles being heated before the admission of the steam, and thoroughly dried after the steam has been exhausted. A vacuum of 15 to 20 inches can be produced in the chamber before the admission of the steam, and any pressures up to 15 lbs. (121° C.) can be obtained.

For fumigating at this station, 3 lbs. of sulphur per 1,000 cubic feet of air space are employed, and for disinfecting with liquids, mercuric chloride (1 : 1,000), carbolic acid, and chloride of lime, are at present used.

[1] *Proc. Am. Soc. Mech. Engineers*, vol. xv.

Heat Disinfection of Buildings.

In former times when mortality from various fevers in gaols and hospitals was so excessive, and had not yet been controlled by sanitation and disinfection, the actual burning of infected areas seemed the only effectual remedy. Sir James Simpson in his book on "Hospitalism" advocated the entire destruction of hospital buildings after, say, ten years. This meant, of course, the erection of buildings only intended to be of a temporary character. Another plan of disinfection by fire is that urged by the late Sir Benjamin Richardson, who in his "Hygeia," recommended that the walls of hospital wards should be of metal, and that these should be purified by the application of fire in the same way that paint is now treated, but in less drastic fashion, by the ordinary workman when redecorating. The whole question of the desirability of destroying hospital buildings periodically was thoroughly gone into some years ago, under the direction of the Local Government Board, with the result that the plan of erecting temporary buildings, and burning them after a certain number of years, was definitely condemned by that authority, and the granting of loans for the erection of temporary isolation hospitals is not allowed.

CHAPTER IV.

CHEMICAL DISINFECTANTS.

The Non-metallic Elements and their Derivatives.

The halogens—Chlorine, chlorides, hypochlorites, chlorates—Bromine, bromides—Iodine, iodine trichloride, iodic and periodic acids and periodates—Fumigation—Chloroform, bromoform, iodoform—Organic haloid compounds.—Fluorine, fluorides, silicofluorides.

The Halogens and their Compounds.

Chlorine.—About the year 1800, Guyton de Morveau in France, and Cruikshank in England, proposed the use of chlorine as a disinfectant. Cruikshank suggested 2 pts. common salt, 1 pt. powdered manganese, with 1 pt. water and ½ pt. sulphuric acid gradually added, for hospital disinfection, giving the amount required for a certain number of beds.

A similar method of generating chlorine is to gently warm one part of manganese dioxide in a granular form with four parts of concentrated hydrochloric acid (5 grms. MnO_2 and 20 grms. HCl give 1 litre of Cl; ½oz. of MnO_2 is abundance for a large room).[1] Letheby recommended one teaspoonful of powdered manganese and half a cupful of strong crude hydrochloric acid, mixed by degrees by stirring in a saucer set on a hot brick.

It should be remembered that the crude acid contains arsenic, which would be evolved as the intensely poisonous arsenious chloride; hence, at a little additional expense, pure acid only should be employed.

Each of these methods requires heat, which presents great difficulties in application. Usually, therefore, the chlorine is evolved from chloride of lime by the action of moderately diluted sulphuric or hydrochloric acid. It has been stated[2] that 1 part bleaching powder with 2 parts of sulphuric acid of specific gravity 1·53, and enough water to cover the powder, evolved three times as much chlorine as when hydrochloric is used. This may be due to the heat generated by the sulphuric acid, as the amounts yielded are theoretically the same, as the following equations show:—

$$CaCl_2O + H_2SO_4 = CaSO_4 + H_2O + Cl_2.$$
$$CaCl_2O + 2HCl = CaCl_2 + H_2O + Cl_2.$$

If the insoluble, and, therefore, solid sulphate of lime keeps back less chlorine than does the deliquescent calcium chloride, the difference in the yield might be explained.

Dr. Mehlhausen[3] of Berlin used 600 grammes of bichromate of potash and 3 kilos. of pure hydrochloric acid, of specific gravity 1·16, for generating chlorine. These weights yield on warming 130·6 litres (405 grms.) of chlorine. He traced a somewhat greater activity to the gas than when prepared by the ordinary processes; this may, perhaps, be due to some chromyl chloride (CrO_2Cl_2) evolved in addition. The cost of this method prevents it from being generally employed.

Chlorine has three possible modes of action:—

1. Especially when concentrated, it can combine directly

[1] Reichardt, *Desinfectionsmittel*, p. 65.

[2] *Lancet*, 1888, p. 110.

[3] *Bericht der Cholera Commission*, 1879, vol. vi., p. 335.

with organic matters, or replace the hydrogen in them, precipitating all albuminous substances and rendering them imputrescible, while at the same time killing microbial life by combining with and coagulating protoplasm. Many of the substituted chloro-compounds are also inimical to bacteria: some of them, such as "chloropicrin," $C(NO_2)Cl_3$, have very pungent odours. Such action would be slow, would scarcely occur at all except in sunlight, but yet would be the only possible action on dry matter. It may account for the antiseptic action of chlorine, as distinguished from its disinfecting power; the former has been questioned, but the experiments of Baxter and Sternberg on dried vaccine lymph seem to be conclusive.

2. The offensive gases of putrefaction are decomposed by chlorine; sulphuretted hydrogen being resolved into sulphur and hydrochloric acid—

$$H_2S + Cl_2 = 2HCl + S.$$

Phosphoretted hydrogen would be also decomposed. Ammonia (and compound ammonias) would give first of all ammonium chloride and nitrogen—

$$8NH_3 + 3Cl_2 = 6NH_4Cl + N_2,$$

hence the copious white fumes frequently noticed when a chlorine mixture is thrown into a dung pit. More chlorine decomposes the ammonium chloride first formed; when this takes place there is always a formation of intensely acrid vapours which attack the eyes and lungs, owing to the production of chlorides of nitrogen and compounds like chloropicrin. In dealing with cesspools, ashbins or privies this becomes strongly prominent in chlorine disinfection. Marsh gas and some other hydrocarbons are not readily attacked by chlorine, but usually also are less objectionable than the gases mentioned above.

3. The common and most important action of chlorine is as an oxidizing agent. In the presence of water, more especially in light, it combines with hydrogen to form hydrochloric acid, and liberates oxygen—

$$H_2O + Cl_2 = 2HCl + O.$$

The oxygen so formed is far more active than atmospheric oxygen, and is in a condition to burn up the putrescent matters and kill the organisms which accompany the putrefaction. But there are several requirements in thorough

disinfection in this way, and amongst these (*a*) *moisture* is shown by the above equation to be an essential, while (*b*) *light*, is strongly assistant.

(*c*) *Quantity*.—Baxter was one of the first to state that the disinfecting action of chlorine and of potassium permanganate depend much more upon the nature of the liquid than upon the specific organism present. Kuhn, Bucholtz, and Haberkorn confirmed this view. They showed that in a fluid like urine which consumes large quantities of chlorine, even though the liquid be deodorized the action on organisms is only feeble until the chlorine is in excess, and that it must be maintained in excess until the last germ is destroyed, otherwise the fermentation will recommence. But if the action has been completed, germs that may afterwards enter from the atmosphere find it an unsuitable medium for growth. From this it follows that the smell of chlorine must be perceptible and persistent for some time, or no good result will have been obtained. Excess of chlorine may be chemically tested for by a paper dipped in a solution of iodide of potassium and starch paste, which is turned blue by free chlorine, or the bleaching of litmus paper may be used as an indication.

Baxter in his experiments mixed chlorine with vaccine lymph, and found that the activity of the latter was not destroyed till it had become acid from the presence of free HCl. Most putrefactive organisms thrive best in alkaline solution; hence the antiseptic power of all free acids in varying degrees.

To kill pure vaccine, Baxter found the minimum proportion of chlorine to be 0·2 per cent. (*i.e.*, soda chlorinata solution, B.P. 1 in 10: chloride of lime, 1 in 100, both acidified). Hofmann[1] gives 0·15 per cent. as sufficient for septic virus.

(*d*) *Time*.—The vitality of the organisms considerably influences the length of time required for sterilization. Sternberg[2] found that 1 per cent. of chlorine in air in six hours made dry vaccine inert. This is a very large quantity, for a room of 50 cubic metres would require at this rate 5 kilos. of bleaching powder, even if all the chlorine were

[1] *Vierteljahrsschrift für gerichtliche Medicin*, April, 1878.

[2] *Bulletin of the U.S. Board of Health*, Washington, 1881.

evolved, which is generally impossible. Baxter stated[1] that air saturated with chlorine by standing over the aqueous solution took thirty minutes to sterilize needles charged with dry vaccine.

These are impossible conditions in practice. Living organisms themselves contain 90 to 95 per cent. of water, hence the disinfectant entering them would be greatly diluted. Moreover, their envelopes are often tough and resisting, especially those of spores. Therefore, more time must be given.

Fischer and Proskauer,[2] from laboratory experiments on spores of anthrax and various bacteria, concluded that for air fumigation at least 0·54 per cent. of chlorine must be present, and considered it more efficacious than sulphurous acid. The experiments of Jalan de la Croix,[3] on the putrefying bacteria of beef tea, gave a surprisingly favourable account of the power of chlorine among the agents which are fatal to low organisms, and placed it next to corrosive sublimate as an "antivirulent."

Vallin[4] threw some doubt on these researches, and asserted that the antivirulent action of chlorine is relatively restricted, and is notably inferior to what would be presumed by the figures given.

Dr. Mehlhausen[5] made a number of experiments, of which the following is an abstract:—

I. In a room of 37 cubic metres with door and window sealed, he placed a number of insects in gauze enclosures, and two vessels of water teeming with vibrios, rotifers, and infusoria. An earthen pot containing 740 grammes (20 grammes per cubic metre) of bleaching powder with a little water, to which he added 1,100 grammes of hydrochloric acid, was also introduced and the door sealed. After nine hours the room was opened and ventilated. The animals were all living; the flies only were insensible, but recovered on the next day. The water in the vessels, originally neutral, had become acid, and gave with nitrate of silver a

[1] *Report of Med. Off. of Privy Council on Disinfectants*, 1875.
[2] *Mitt. aus d. Kaiserl Gesundheitsamte*, Berlin, 1884.
[3] *Arch. für experiment. Pathologie*, 1881.
[4] *Traité des Désinfectants*, 1882, p. 118.
[5] *Bericht der Cholera Commission*, 1879, vi., p. 335.

copious precipitate of chloride. All the bacteria were dead. The 740 grammes of chloride of lime had given 59·7 litres of chlorine—*i.e.*, 1·613 litre per cubic metre, or *0·1613 per cent.* in the air (about the amount mentioned by Hofmann, as above given), whilst some had been undoubtedly wasted by non-evolution and by leakage.

II. With the same conditions as before, but with double the amount of chlorine. The vessel contained fermenting urine. In eight hours there was much residual chlorine. Most of the higher organisms were killed; the urine had become acid, but the bacteria and spirilla were still moving.

III. Equal parts of common salt and manganese dioxide, with 2 parts of sulphuric acid and 1 part of water, were warmed together, whilst putrid urine and dysenteric stools in wide flat dishes were exposed for twenty hours to the gas. On opening, only a feeble odour of chlorine was noticed, as it was masked by the effluvia from the stools and urine. Some of the organisms were only benumbed, and recovered their activity in fresh air. The liquids were very acid, and had not entirely lost their fœtid odour.

IV. In another room of 48 cubic metres a glass balloon was placed containing 600 grammes of bichromate of potash and 3 kilos, of hydrochloric acid of specific gravity 1·16; by warming, 405 grammes of chlorine were evolved, equal to 2·7 litres per cubic metre, or *0·27 per cent.* Under these conditions all the organisms were killed, but the time required was not stated. The process is, however, long, difficult, and more expensive than the others, the cost being given as 4 centimes per cubic metre, or about 1/6 for disinfecting a room 11 feet square.

Vallin maintains that fumigations with chlorine are of little advantage, and are decidedly inferior to those with sulphurous acid. The disengagement of chlorine is incomplete, unless stirred and heated constantly, which is almost impossible in ordinary practice. The facility of "sulphuring" is, on the other hand, of the greatest value, and the expense is about four or five times less.[1]

Jeannel[2] noticed that chlorine seemed to have only a temporary action on certain vibrios, as he was able by means

[1] See later, *Sulphurous acid.*

[2] *Union Médicale*, Sept. 28th, 1871.

of ammonia to restore them to activity after they had been subjected to the influence of chlorine for a long period.

The experiments of Sternberg[1] concerning the action of chlorine on infusoria and micro-organisms show that the resistance of the latter is considerable. In an experimental room of 10 litres capacity, he placed 28 grammes of chloride of lime. It was an hour and a half before the movements of the bacteria contained in a drop of putrid meat infusion ceased, although the watch glass holding the liquid was directly exposed to the gas. (If he did not acidify, the only chlorine evolved would be that liberated by the small quantity of carbonic acid in the air present—namely, about 0·071 per cent.—which is too small a proportion, if we take Hofmann's minimum of 0·16 per cent., or Baxter's 0·2 per cent. be admitted.[2] But the total amount would still be immense if it could be absorbed by the drop of fluid, as it would reach 7 grammes of chlorine in the 10 litres of air.) Sternberg did not consider the movements definitely destroyed until after an hour's exposure to fresh air, they had not reappeared.

Dr. Cash[3] subsequently studied the action of chlorine, and endeavoured to determine the comparative value of the halogens and of sulphurous acid in destroying the virus of anthrax and tubercle; he concluded that the halogens do not present any great differences when employed in solutions, the strengths of which are proportional to their atomic weights, though chlorine was the least active and iodine the most. This would oblige us to use 127 parts of iodine for 80 of bromine and 35·4 of chlorine. He found that when employed in dilute solutions they did not disinfect. (That is, below Baxter's limit of 0·2 per cent.) He prefers sulphurous acid if the disinfecting agent be employed as a gas, but considers it better to employ a solution of the gas, if possible.[4]

One volume of water dissolves approximately 2 volumes of chlorine gas, and as one litre Cl weighs 3·169 grammes, cold saturated chlorine water contains 0·634 per cent. of weight of Cl.

[1] *Bulletin of National Board of Health*, Washington, July 23rd, 1881.
[2] See later, under *Chloride of lime.*
[3] *Pharm. Journ.*, 1887, p. 485; *L. G. B. Sixteenth Annual Report.*
[4] See later, *Sulphurous Acid.*

(*e*) *Contact.*—Intimate contact between the gas and the centre of infection must be assured. Reichardt remarked that chlorine failed with large masses of putrescible matter like fæces, and must be supplemented by the addition of metallic salts, etc. For if all easily decomposable matter be not destroyed, a recommencement of putrefaction is not prevented.[1] Klein,[2] however, used chlorine fumigations in stables for disinfection from swine plague with success. Care must be taken not to give a false security by illusory means. Probably in many cases it is better to rely on purification being accomplished naturally by air and moisture than run the risk of natural decomposition being retarded by the employment of inefficient quantities of antiseptics. It must be remembered that manure that has been treated with chlorine or chloride of lime loses agricultural value on account of the destruction of its ammonium salts. On the other hand, if chloride of lime is sprinkled over fæcal matter before removal, it destroys any offensive gases that may be evolved.

It cannot be too strongly emphasised that air cannot be disinfected and still remain fit to breathe. Wernitz[3] condemns all fumigations as "illusory specifics," since "we require a body which shall come in intimate contact with atmospheric dust, and act for a long time on it." Vallin says "disinfection of air is useless and gives a deceitful security. To make a strong odour of phenol, or put a basin of chlorine in a corner, is, with regard to destruction of virus, an operation quite futile, as the virulent particles in air are probably protected by an envelope of dried albuminous matter."

Chloride of Lime and Hypochlorites.—With alkalies and alkaline earths in the cold, chlorine gives mixtures of chloride and hypochlorite which have been long known as useful disinfectants. In all these preparations the "available" or active chlorine is that present in the free state or as hypochlorite, the portion present as chloride being practically inert as regards disinfection. The soda and potash preparations are more expensive than that with lime, but have many medicinal and toilet advantages, and

[1] *Reichardt, Desinfectionsmittel,* p. 57.
[2] *L. G. B. Thirteenth Annual Report.*
[3] *Desinfectionslehre,* 1882.

do not leave behind a deliquescent residue. Some samples contain an objectionable excess of alkali.

Liquor sodæ chlorinatæ, B.P., chlorinated soda, or "Eau de Labarraque," has a strength of 2½ per cent. of available chlorine. It is used in surgery diluted with 10 parts of water (equal to Baxter's effective strength of 0·2 per cent. Cl) as an antiseptic lotion, and is refreshing and non-irritant. By its decomposition it produces a small quantity of common salt. It has also been employed as a mouth wash.

"Chloros" is a solution of sodium hypochlorite, prepared by the United Alkali Co. and guaranteed as containing 10 per cent. by weight of "available chlorine (p. 84). It is directed to be diluted with 100 volumes of water, making the strength about one-tenth per cent. The reports on its employment on a large scale at Glasgow during the late plague danger in 1901 are very favourable. The hands can be immersed even in the 10 per cent. liquid without unpleasant results.

"*Eau de Javel,*" first made by Percy in 1792 at the Javel works near Paris, by passing chlorine into a solution of crude potashes, was the earliest known of these bleaching compounds. The potash preparation is now rarely made, having been replaced by the cheaper soda compound, which is commonly known by the same name. The orders of the French Prefecture recommended 1 part of Eau de Javel of 18 Baumé to 100 parts of water for flushing closets and washing walls, etc.

The constitution of these liquors is similar to that of chloride of lime solutions. When made from the carbonates, instead of the caustic alkalies, they contain free hypochlorous acid, HClO, and are more active and less stable.

Max Muspratt has succeeded in obtaining a hypochlorite of soda solution with 35 per cent. of available chlorine, which is, except for hydrogen peroxide of unmarketable strength, the strongest oxidizing solution in the cold (*J. Soc. Chem. Ind.*, 1898, 1100). He also produced sodium hypochlorite in the crystalline state. These concentrated products, however, are at present difficult to keep, though it must be remembered that even chloride of lime has its dangers which have led to accidents.

Mumford and Newlands (pat. 20,884, 1901) dry up a

sodium hypochlorite solution by adding anhydrous sodium carbonate. The powder is said to be stable.

"Chloride of lime" or bleaching powder, obtained by passing chlorine over moist slaked lime, has the advantage of being a dry powder, which is more easy of transport and keeps better than the soda and potash preparations. It is a species of combination of chloride and hypochlorite, essentially of the formula $CaCl_2O$, and breaks up into its constituents on solution in water. The hypochlorite is strongly alkaline, and is acted on by the carbonic acid of the air giving carbonate of lime and hypochlorous acid.

$$2CaCl_2O = CaCl_2 + Ca(ClO)_2$$
$$Ca(ClO)_2 + CO_2 + H_2O = CaCO_3 + 2HClO$$

In contact with organic matter the hypochlorous acid splits up into hydrochloric acid and oxygen, and it is on this liberated oxygen that its value as a disinfectant depends. The calcium chloride remains behind as a deliquescent salt, and this is an objection to bleaching powder being mixed with lime for white-washing, as the surface remains damp. It is important to remember that chloride of lime must be acidified, either slowly and spontaneously by aerial carbonic acid, or by the addition of hydrochloric or sulphuric acid or even vinegar, for any chlorine to be liberated. Weak acids only decompose the hypochlorite, leaving the chloride untouched, and evolve hypochlorous acid. Strong mineral acids, on the other hand, evolve chlorine.

To prove the necessity of acidification, D'Arcet and Gaultier de Claubry showed that air deprived of carbonic acid by a potash wash-bottle, and then passed over chloride of lime, was not disinfected.

Good bleaching powder contains 34 per cent. of available chlorine. It is best used in the proportion of 1 part to 10 or 12 parts of water. It should be freshly prepared, and kept from light and air. When old it becomes damp and is then of inferior value.

Similar preparations of aluminium and magnesium hypochlorites have been made by precipitating a solution of chloride of lime by sulphates of aluminium or magnesium. The latter has no special advantage, but the former has in addition the mordanting and clarifying and antiseptic properties of other aluminium salts (see Chap. VII., p. 173),

and might deserve more extended use. It is commercially used for bleaching paper pulp, under the name of Anderson's solution. The American "standard solution of chloride of lime" is thus described:—"Dissolve chloride of lime containing not less than 25 per cent. of available chlorine, 6 ounces to 1 gallon of water (4½ per cent.). Use 1 quart for each discharge in cholera, typhoid, etc. Mix well, and leave in the vessel at least one hour before being thrown away."[1]

For disinfecting clothes, the diluted Eaux de Javel or Labarraque are better than chloride of lime. The fabrics must be washed soon after, or the fibres will be rotted. Of course the colours will be more or less affected. Jaeger used a paste of equal parts of water and bleaching powder for disinfecting tuberculous sputa.[2]

It must be remembered that chlorine and the hypochlorites also act energetically on other substances, so that any mixture of them with other disinfectants can only be endorsed by an experienced chemist, for, as a rule, these are only to be used apart.

One part of chloride of lime to 100 of water forms a liquid for washing the person in infectious diseases. The odour is most persistent, and may even convey a false sense of safety when the effective limit has long been passed. Semmelweis, however, in 1846 succeeded in stamping out of Vienna endemic puerperal fever by its means, and Sir Spencer Wells advocated its use in this country.[3]

Liebig contended that the continued action of chlorine or hypochlorites, as in the wards of hospitals, leads to lung diseases in the patients and attendants. Pettenkofer and Lehmann[4] say that 0·001 to 0·005 per cent. of chlorine affects the respiratory organs; 0·04 to 0·06 per cent. produces dangerous symptoms; and over 0·06 per cent. soon proves fatal. Undoubtedly chlorine will cause chronic bronchitis if in quantity, and disinfection with chlorine involves such a percentage of the gas as absolutely necessitates the removal of animals and plants from its vicinity.

[1] *Report of Committee on Disinfectants of American Public Health Association*, p. 235.

[2] *Arb. a. d. Kais. Gesundh.*, 1889.

[3] *British Medical Journal*, 1892.

[4] Munich Acad., 1887.

The *Berichte der Choleracommission des Deutschen Reiches,* 1879, condemns the use of chlorine as being dangerous, and Koch obtained unsatisfactory results with chloride of lime.[1]

The same, however, is the case with sulphurous acid, nitrous gases, and still more with bromine and iodine, which are all intensely poisonous.[2] The physiological action, coupled with the fact that chlorine gas corrodes metal fittings and rots fabrics, has led in great part to its disuse except for the disinfection of sewers and closets. Angus Smith,[3] on the other hand, points to the healthy appearance of men employed in bleaching factories; he attributes this to the purification of the air. Notwithstanding many objections, chlorine must be regarded as the most powerful of the disinfectants, being the only convenient gaseous body that can quickly destroy organic matter and consequently ensure perfect disinfection.

"*Chlorozone*" was the misleading title given to a bleaching-soda preparation patented by Count Brochocki in 1876. "Chlorogene" was another mixture of the kind.[4] A mixture of hypochlorites and permanganates, also called "Chlorozone," was formerly advocated. It was probably made by passing a current of chlorine through milk of lime, or a solution of soda or potash, in which finely ground manganese dioxide was suspended, or to which the manganous residues from the manufacture of chlorine were added. The chlorine oxidized the manganese compounds to permanganate, and at the same time formed hypochlorite. Such a solution would be attractive from its crimson colour, and would at the same time combine the oxidizing properties of both these agents.

Chamberland and Fernbach in a paper on the "Disinfection of Public Places and Dwelling Rooms"[5] proposed to make hypochlorite solutions more active by heating them, but they are thereby converted into chlorates.

[1] *Mitt. a. d. Kais. Gesundh.*, vol. i., 1881.

[2] *Wirkung der verdunnten Luft a. d. Organ.* Fränkel & Goppert, Berlin, 1883.

[3] *Disinfectants and Disinfection,* 1869, p. 49.

[4] *Bull. Soc. Ind.*, Rouen, 1889, 375.

[5] *Ann. Inst. Pasteur,* 1893, vii., 433.

Sheridan Delépine[1] used chlorinated lime for disinfecting rooms which have been contaminated by tuberculous patients, as follows:—(1) The walls, ceiling, and floor are washed with a solution of chlorinated lime (1 in 100) in the same way as lime or whitewash is usually applied, and the process should, for safety, be repeated three or four times in succession; (2) the room should then be closed, a small safe petroleum stove being first placed in the middle, and precautions taken to prevent any chance of fire; over this stove, a large tin basin full of water or bleaching powder solution should be placed. To secure acidity to the air, he further suggests suspending in the water bath a capsule containing hydrochloric or acetic acid. Three hours is sufficient time for an ordinary room, and 6 ozs. of bleaching powder, using 3 pints of water for each washing, is the quantity he recommends. The quantity of chlorine evolved seems rather uncertain. W. E. Crow and Frank Browne, at Hong Kong, during the plague in 1894, used free chlorine generated from ½ lb. chlorinated lime, mixed with 1 quart of water and 1 quart of dilute sulphuric acid (1 in 5). This quantity was used for each room.

The "Hermite" or Electrolytic Process.—About 1859, Charles Watt discovered that when a solution of a chloride of the alkalies or alkaline earths was electrolysed, a solution similar to bleaching liquid was formed. It presumably contained chlorides and hypochlorites, but apparently was more active than a solution prepared in the ordinary way. Magnesium chloride was said to be preferable. Such a solution, originally intended for bleaching paper-pulp, was applied by M. Hermite to sanitation, using sea-water, containing as it does the chlorides of sodium, calcium, magnesium, and potassium, as a cheap and suitable raw material. He employs a special form of "electrolyseur" for effecting the electrolysis, and pumps the solution through pipes to the place of use, for domestic purposes, and for local flushing of sewers, latrines, etc. Dr. Piton's report to the Corporation of Brest, referring to experiments on this system at Nice, stated that the Hermite solution, diluted to a strength of about ¼ gramme of free chlorine per litre, did sterilize the fæcal matter in the sewers, but that, in spite of

[1] *Med. Chron.*, May, 1894.

the rapid absorption of chlorine, the disintegration of paper and fæcal matter was no more rapid than when ordinary water is employed. The system was tried at Worthing in the early part of 1894, and the Medical Officer of Health, Dr. C. Kelly, in a report incorporating the chemical and bacteriological analyses by Dupré and Klein, "dismisses the experiences of the trials made by the Worthing Corporation as having failed to realise the claims of the inventor, besides involving serious considerations of expense, both in the production of the fluid and the method of applying it to houses." This report was questioned by the English agents, Messrs. Paterson and Cooper, who have formally protested. Dr. Rüffer and Sir H. Roscoe reported more favourably on the process, and it was further tried at Havre, l'Orient, and Nice.

In the Hermite patent, No. 22,279, 1893, the apparatus is described, and the strength of the fluid obtained is stated to be 2 grammes of free chlorine per litre, and for use it is recommended to be diluted six or seven times. A current of 300 amperes at a pressure of 6 volts is required to decompose the sea water in the electrolyseur. In patent No. 6,495, March 31, 1894, a method of protecting the iron pipes from corrosion by the chlorine is covered.

The *Lancet* Report on the Hermite process and the experiments at Worthing[1] came to the following conclusions:—

By electrolysis of the magnesium chloride in the sea water, magnesia and chlorine are liberated, which subsequently combine to form magnesium hypochlorite $Mg(OCl)_2$ and magnesium chloride. This liquid may be regarded as the magnesian equivalent of bleaching powder solution. The magnesium hypochlorite dissociates into magnesia, which deposits on the walls and floor of the electrolyser, and free hypochlorous acid, which remains in solution.

$$Mg(OCl)_2 + 2H_2O = Mg(OH)_2 + 2HOCl.$$

The Hermite solution then practically resolves itself into a dilute solution of hypochlorous acid, and may be cheaply imitated by passing carbonic acid through a solution of ordinary bleaching powder. It is admitted, however, that this "artificial Hermite" gave in bacteriological examination "varying results, and could not be depended on to

[1] *Lancet*, May 26th, 1894.

exert constantly an equivalent action to the Hermite solution." Chemically, however, the two solutions exhibited very close resemblance.

The strength of the electrolysed sea water in chlorine, or its equivalent, as determined by the arsenious acid process[1] is 0·5 gramme Cl per litre. Urine at once acts on it, depriving it of about half its chlorine strength.

In comparative experiments on the action on ordinary stools of Hermite fluid, bleaching powder solution, and milk of lime $2\frac{1}{2}$ and 1 per cent., it was observed that, as expected, the bleaching powder was not so immediate in its effect, but in a longer period the final result was similar. "Although in consequence of this the bleaching powder does not exert so rapid and immediate effect as the more unstable Hermite solution, yet the weaker solutions of the former, owing to their stability, in the end produce a much more complete process of sterilization than in the case of Hermite solutions of similar dilution." The action of the *full-strength* Hermite fluid on the pathogenic organisms of diphtheria and of cholera, and the *Staphylococcus pyogenes aureus* was very satisfactory; but in the case of anthrax it was less conclusive, as the cultures used were proved to be somewhat feeble. Both gelatine plate and broth cultivation were tried. It was far more efficacious than even strong solutions of phenol. As compared with mercuric chloride, the report gives the preference to the Hermite fluid as a practical disinfectant. It sees, however, no advantage in the Hermite solution over the product obtained by treating chloride of lime in solution with carbonic acid.

In an elaborate subsequent report by Roscoe and Lunt of experiments at Worthing[2] the main conclusions are that electrolysed sea water when dilute is very unstable, and requires to be used soon after preparation, that it fails to dissolve paper or solid fæces or to sterilize the interior of the latter, that it is an excellent *deodoriser*, but is not by itself applicable as a process of sewage *purification*.

A Hermite patent (Paterson and Cooper, 2197, 1896) proposes to prevent the loss of strength by adding a small

[1] *Methods of Analysis*, Chap. xvi.

[2] *Journ. Soc. Chem. Ind.*, 1895, p. 224.

proportion of soda or milk of lime. Crawford (14,852, 1896) strengthens the liquid by cooling during electrolysis.

The *Lancet* found that full-strength Hermite Fluid of 0·02 per cent. chlorine strength was fatal at once to diphtheria and cholera bacilli, to typhoid in 5 to 10 minutes, and in one hour to anthrax *spores*.

"Electrozone," is a liquid similar to the Hermite, made according to the Woolf process by electrolysing sea water or weak brine (2 or 3 per cent. NaCl), and was originally introduced in America. It is a yellowish fluid of chlorous odour, sp. gr. about 1·02, and contains hypochlorites and chlorides, the "available chlorine" (that of the former), being, according to my analysis, about 0·355 per cent., or practically decinormal. It has been extensively used in the States for disinfecting and deodorizing sewers, garbage, etc., and reports from several American chemists and bacteriologists are eminently favourable. At Brewsters, N.Y., it has been used for some years to purify a bad water which formed a portion of the New York City supply. E. W. Martin, Chemist to the Health Department, N.Y., states that 1 part to 100,000 of water "largely oxidized the nitrogenous organic matter, converting the greater part of the free and albuminoid ammonia, and all the nitrites, into nitrates. It also killed most, and in some cases all, the bacteria."

A series of trials were conducted in 1898 by Profs. Robinson, Kanthack, and the author, as to the treatment with "electrozone" of the sewage effluent at Maidenhead. One part of the fluid was added to from 400 to 800 parts of effluent, the amount being regulated so that after the mixture had run through an open channel for two minutes, the liquid at the outfall still gave a blue colour with potassium iodide and starch. The chemical and bacteriological analyses agreed in showing that electrozone used as above effects little lowering of the organic matter in sewage, but has a marked germicidal action, and that if the organic matter be previously reduced by filtration or by a bacterial process to a low limit, electrozone will produce an effluent nearly colourless, free from odour, and containing very few bacteria.

"Meditrina" is a slightly stronger form of the above, prepared for medical and surgical use.

The reason for the small action on the organic matter was

elucidated in the author's report. The sewage was found to require for complete oxidation about 11 parts of O per 100,000, whilst the amount of "available Cl" added was only about 0·55 parts per 100,000. As 35·5 parts of hypochlorous Cl are equal in oxidizing power to 16 parts of O, it will be seen that the amount of fluid added must be increased nearly fifty-fold to effect complete oxidation. This only supports what is emphasized in other parts of this volume, that although many disinfectants, *if used in sufficient quantity*, can kill bacteria and destroy offensive matter, the amount required is far in excess of what is prescribed, and becomes almost prohibitive as to cost. Chlorine and hypochlorites, and indeed other chemical disinfectants, practically fail when applied to the solid matters of sewage. Although the chlorine, when brought in contact with the germ, is capable of killing it, it does so mainly by oxidizing the organic matter in the germ; but, on the other hand, in presence of a large amount of organic matter, the chlorine often expends itself on the latter before it has time to sterilize the organisms.

Inasmuch as all hypochlorite solutions are alkaline, and it is known that the growth of bacteria is encouraged by weak alkalies, and hindered by acids, it has been proposed to acidify these solutions so as to evolve chlorine or hypochlorous acid. Outenin-Chalandre (Eng. pat. 15,834, 1896), during the electrolysis of salt solution, adds hydrochloric acid continuously; while, however, alkaline solutions tend to dissolve albuminoid matters, and therefore penetrate them better, free chlorine and HClO precipitate them, thereby being removed as an insoluble combination, which crusts over the larger particles, and may protect the interior.

Haüssermann[1] gives details of the cost of plant for electrolysing brine.

Some recent investigations on the quantity of "available chlorine" required to produce an effect on organisms may be quoted. It must be repeated that organisms differ greatly in their resistant powers, a large number disappearing rapidly and with weak solutions, while spore-bearing forms

[1] *Dingler's Polyt. J.*, 1895, 296, p. 189. See also Schoop, *Zeits. f. Elektrochem.*, 1895, ii. [10], 209.

like B. anthracis are most persistent, and that time, temperature, acidity, or alkalinity, light, nature of the matters in solution, and vigour of the culture used, play a most important part in the results, the interference of these factors accounting for the varying results sometimes recorded. A "reduction of the number of organisms" is often easily attained, whereas "absolute sterility" may involve perhaps a thousand times as much reagent, and an equivalent increase in the cost. In the following examples, Cl means available chlorine, *i.e.*, that which is either free or belongs to the hypochlorites. "Parts" means parts per 100,000.

Kanthack in 1898 found that 0·3 to ·36 parts of Cl reduced the organisms in sewage effluent from innumerable to 10—50 per cubic centimetre.

In a laboratory experiment in the same year the author observed that when sewage was treated with 1·77 parts of Cl, although from 44 to 66 per cent. of this immediately combined with organic matter, plate cultivations taken after fourteen minutes showed no growth at room temperature in three and a-half days. Professor Delépine, of Owens College, finds that a 1 in 50 solution of chloride of lime (= 0·66 per cent. Cl), disinfects tuberculous matter, while 1 in 10 (= 3·3 per cent. Cl) kills anthrax spores in a very short time, and that the latter solution will keep in the dark for over twelve months. A liquid of 1 in 50, or even 1 in 100 strength is syringed over the walls, and the room closed till the next day. Drs. Sims Woodhead and Cartwright Wood have repeated and confirmed Delépine's results, which may also be illustrated by the earlier work of Nissen and Bolton. The former found as the effective times and strengths:[1]

Organisms.	Time in minutes.	Bleaching powder per cent.	Available chlorine per cent.
Typhoid and cholera	5	0·12	0·04
Anthrax *bacillus*	1	0·10	0·033
Staphyl. pyogenes aureus	30	0·2	0·066
Anthrax *spores*	30	5·0	1·67
" "	70	1·0	0·33

[1] Nissen: "Disinficierende Eigenschaft des Chlorkalks," *Zeit. f. Hyg.* viii., 1890.

Bolton states that 1 in 2000 of chloride of lime (= 0·017 per cent. available Cl) destroyed typhoid and cholera germs in two hours, while anthrax spores required a 1 per cent. solution (0·33 per cent. Cl).

Prof. Boyce states that 3 per cent. of sodium hypochlorite solution (= 0·3 per cent. of available Cl) killed B. coli., typhosus, and Sp. choleræ in both cultivations in two hours, but not B. anthracis when spore-bearing. One per cent. (0·1 per cent Cl) in two hours killed all except B. subtilis and anthracis.

Dr. G. C. Clayton further found that anthrax spores required 2·5 per cent. Cl acting for thirty minutes, adding that 5 per cent. Cl acted in one minute, 0·5 per cent. mercuric chloride in the same time, while phenol failed to sterilize.

In Dr. Klein's experiments, sodium hypochlorite was diluted with definite volumes of sterile distilled water, and separate tubes inoculated with nine species of organisms, including some anaerobic and spore-bearing forms. After definite times, subcultures were made, and incubated at 37 deg. C. for four days (B. enteritidis at 20·5 deg. C. for six days). By this time any living microbes would have had ample time and opportunity of producing easily visible growth. The non-sporing microbes were killed by 1 in 200 solution (= 0·05 per cent. Cl) in five minutes, while weaker solutions required an exposure so long as to be impracticable. Anthrax and enteritidis were killed by 0·1 per cent. Cl in 1½ hours. In sewage 1 of hypochlorite in 100 of fluid destroyed all non-sporing microbes in 10 minutes, B. mesentericus apparently in thirty minutes.

Chlorates.—Being more stable than the hypochlorites, the chlorates, although they contain more oxygen, give off neither oxygen nor chlorine unless a strong acid be added. Such a mixture is a very strong oxidant, but it evolves besides chlorine, more or less of the explosive and poisonous chlorine oxides known as "euchlorine." Wiederhold recommends cholera excreta to be treated with potassium chlorate and hydrochloric acid. The odour of the gases evolved is very unpleasant, and powerfully attacks the eyes. The action is very rapid, but is soon exhausted; an objection which, independent of cost and unpleasantness, renders other preventives preferable.[1]

[1] Reichardt *Desinfectionsmittel*, p. 95.

For the use of the peroxide and other chlorine compounds in water purification see Chapter XII.

By themselves, chlorates are mildly antiseptic. Dr. O'Neill found[1] that the chlorates of potassium and sodium had no preventative action on beef tea. Perchlorates are similar.

Hydrochloric Acid.—Since almost all bacteria grow best in neutral or alkaline solutions, and many are killed by even weak acidity, the mineral acids are valuable disinfectants. Davaine[2] stated that the virus of anthrax or septic fever is definitely destroyed by the following proportions of acids:—

	Anthrax.	Septicæmia.
Hydrochloric...	1 in 3000	
Sulphuric	1 in 5000	1 in 1500
Chromic	1 in 6000	1 in 3000

Vallin, from his own experiments, concluded that a larger amount is required. See further p. 136 and Chapter XII.

Acid fumigations for disinfection, especially with hydrochloric acid, were introduced by Guyton de Morveau in 1805. Previously, in 1773, the stench from the catacombs under the church of St. Etienne at Dijon (which, of course, would be very ammoniacal) was entirely removed in twenty-four hours by pouring 2 lbs. of sulphuric acid on 6 lbs. of salt in a vessel heated by a brazier of hot cinders.

$$NaCl + H_2SO_4 = NaHSO_4 + HCl.$$

The next year the hospital at Dijon, where typhus was raging, was successfully disinfected by the same means. After several other trials, this process was strongly approved by the Academy of Sciences. For 350 cubic metres of space, 200 grms. of salt and 240 grms. of sulphuric acid of 60° B. were recommended.

Guyton de Morveau[3] mentions that "Dr. Cabanellas, in the terrible epidemic in Andalusia in 1780, having exposed to the simple vapour of hydrochloric acid for 16 days,

[1] *Army Medical Report*, 1872, p. 202.

[2] "Virus de Septicémie," *Gaz. Med.*, Jan. 10th, 1874.

[3] *Traité*, 1805.

pieces of very fœtid flesh, there remained not the slightest odour of putrefaction."

Its penetrating power and solubility, combined with cheapness and facility of employment, are its chief merits. The gas is less irritant than chlorine, but has a powerful pungent odour. Although it is now seldom used, it is well worth further experiment. The danger of the presence of volatile chloride of arsenic must be remembered.

Powders evolving HCl slowly have been proposed for dusting in stables. Stackmann and Retschy[1] take sodium bisulphate and native kieserite (or other similar mineral containing a small percentage of chloride), both separately ground and dried and then intimately mixed. When sprinkled on moist dung or litter it is claimed that sufficient HCl gas is evolved to disinfect the air of the stable without injuring the animals therein.

Against the employment of the gas are the experiments of Pettenkofer and Lehmann,[2] in which animals exposed to 3·4 per cent. of the acid in air for one and a-half hours were seriously affected, and many died. Strong men can only stand 0·5 per cent. for a short time, and the limit for workmen used to it is 0·1 per cent. Recent experiments have shown that less than this is destructive of a large number of pathogenic bacteria.

Chlorides.—Many of the chlorides have marked antiseptic properties. Those of the heavy metals, such as iron, aluminium, and zinc, will be noticed under the respective metals.

Sodium chloride, common salt, is generally employed for the preservation of meats, butter, etc. This it does less by its own antiseptic power than by removing in the brine the soluble and more putrescible organic constituents, and by hardening the remaining insoluble fibres. The brine becomes sometimes contaminated with ptomaines, and parasitic low organisms are produced. M. Goubaux has shown that it can sometimes acquire a high degree of toxicity. However, it is generally thrown away and the meat washed before use.

[1] Patent 20,712, 1899.

[2] Munich Acad., 1887, 179.

Sodium chloride is not a disinfectant. Pringle,[1] who was one of the first to introduce direct experimental methods in the study of disinfectants, in his *Mémoire sur les Substances septiques et antiseptiques,*[1] which is of classical interest, and contains details of a series of most carefully devised experiments, found sodium chloride so weak an antiseptic that he placed it the lowest in his scale of bodies investigated. In further experiments he proves that sodium chloride more frequently hastens putrefaction, for, in the proportion of 10 to 20 grains to 2 grains of beef and 2 ounces of water, the salt softens and dissolves the meat, and "by a septic virtue favours its digestion." He cites other authors who have admitted the "putrefiant" nature of sodium chloride.

Bouley,[2] and Arloing, Cornevin & Thomas[3] find that even a saturated solution of salt is without action on the virus of anthrax.

In water, common salt, according to Percy Frankland,[4] whilst enormously stimulating the multiplication of many bacteria, exerts a directly and highly prejudicial effect on the typhoid bacillus, and Forster[5] stated that it destroyed the cholera organism. However, common salt is only indirectly an antiseptic, and cannot be called a disinfectant.

Bromine, early used by Ozanam against false membrane in diphtheria, has the advantage of a liquid form, yet high volatility, but the defects of an odour and action on the mucous membranes which are worse than those of chlorine, and of being intensely corrosive. Pettenkofer's limit of human endurance of the vapour in the air is ·003 per cent. Its chemical action is similar to that of chlorine, standing as regards activity between Cl and I. Among early investigators, Wernitz,[6] Jalan de la Croix,[7] Bucholtz[8] and others have given figures for the bactericidal efficiency of the halogens, which obviously depend on the kind of organism

[1] *Acad. des Sciences,* 1750.
[2] *Médicine Vétérinaire,* p. 467.
[3] *Lyon Médical,* June, 1882.
[4] *Proc. Roy. Soc.,* lvi., 535.
[5] *R. Acad. of Science,* Amsterdam, April, 1890.
[6] "Wirkung der Antiseptica." *Inaug. Dissert.,* Dorpat, 1880.
[7] "Verhalten des Bakterien," *Archiv. f. Exp. Pathol.,* 1881.
[8] *Archiv. f. Exp. Pathol.,* vol. iv., p. 1 to 80.

and the conditions. Arloing, confirmed by Koch, finds that bromine is the most powerful of all destructives to the virus of anthrax and tubercle, "even killing the dried virus on which chlorine does not act." Malméjac has also a comparison of the halogens.[1]

The Prussian Government ordered (March 13th, 1879) that when strong disinfection of stables was necessary, after removal of the animals, for every 18 cubic metres of space a flask of 250 grammes of bromine should be planted in sand, iron articles being as far as possible removed and apertures closed, the flask then upset, *the operator quickly retiring*. In twenty-four hours the place is opened, and then ventilated for twelve hours before using. The method seems an excellent one for this purpose, in expert hands. Silicious earths[2] and porous rods[3] have also been used as vehicles for the bromine.

Bromides and bromates when mixed and treated with an acid decompose one another, like the corresponding Cl and I compounds, evolving the halogen. The same is the case with a solid mixture of sodium or potassium bromide and bromate with sodium bi-sulphate known as "Bromidine" (Patent 6191, 1886); by the agency of moisture bromine is liberated:—

$$5\ NaBr + NaBrO_3 + 6\ NaHSO_4 = 6\ Na_2SO_4 + 3\ H_2O + 3\ Br_2$$

Bromine is more soluble in water than chlorine; its solution containing 3 per cent. Br. Wilson states[4] that bromine water of 2 per cent. strength destroyed B. anthracis in one day.

"Bromonaphthalene nightlights" give off Br only on burning,[5] and are objectionable. Dr. C. R. A. Wright patented the use of chlor- or brom-naphthalene in resin soap, also as powder mixed with sawdust or plaster of Paris.[6]

The minimum quantity of bromine required for sterilization would seem to be about the same as that of chlorine, viz., 0·05 per cent., but must vary greatly with the conditions.

[1] *J. Pharm. Chim.*, 1900, xi., 364.
[2] *Mittheil. Kais. Gesund.*, Berlin, 1884.
[3] Patent 254, 1883.
[4] *Hygiene*, 1892, p. 525.
[5] *Journ. S. Chem. Ind.*, 1890, p. 407.
[6] Patent 4950, 1893.

There is no doubt that bromine is a powerful disinfectant, but its use is limited by its dangerous qualities.[1]

The author has pointed out at Leeds and elsewhere that the principle of disinfection by chemical oxidation as frequently practised is costly and unsound, inasmuch as so a large proportion of the agent is wasted on the inert matters present.

Iodine as an oxidizer is more feeble than Cl and Br, but it combines more readily, in dilute solutions, with the protoplasm of organisms, thereby poisoning them. It is not a good deodorant, and it produces brown or blue stains on organic materials. Being a solid, it is convenient and portable. Its solubility in water is only about 1 in 7,000 (iodine water), hence for local application, as in surgery, it is dissolved in alcohol (tinctura iodi, 1 in 40) or in KI (liquor iodi, 1 in 20). Its vapour (vapor iodi) is eight and a half times heavier than air, and easily condenses, therefore it is difficult to diffuse. It has proved of service in phthisis, etc., when properly diluted.[2] The contrivance for producing the vapour include a variety of lamps besides the following iodised candles:—Casson and Brown (I and salicylic acid, slow burning yields I and phenol); "Sussex patent nightlights" (iodoform); Watson and Fulton (iodine and sulphur)[3]; A. J. Shitton has patented[4] solutions of iodine in alkaline iodides diffused by a spray-producer.

Davaine and Marchal de Calvi were the first to introduce iodine as an antiseptic. The former found that 7 mgms. of I killed B. anthracis in 1,000 of liquid.[5] Griffiths states that 1 part in 10,000 destroyed Sarcina lutea in half an hour.[6] Dr. Williams claims it as greatly reducing the number of tubercle bacilli. "We can inject with impunity into the blood of a dog, for each kilo. of body weight, 0·02—0·03 grm. of I dissolved in 2 parts of NaI, equivalent to 1·4 to 2·1 grm. for an ordinary man. Beyond this it is poisonous,

[1] Also see *Reichs. Med. Anzeig*., No. 7, s. 100; *Wiener Med. Blätter*, 1897, No. 1-3; *Amer. J. Med. Sciences*, June, 1897.

[2] *Proc. Roy. Soc. Edin.*, xv., 54.

[3] Patent 10,876, 1885.

[4] Patent 2537, 1889.

[5] *Bull. Acad. Médicine*, July 27th, 1880.

[6] *Proc. Roy. Soc. Edin.*, xv., 37.

and death occurs in twenty-four hours. KI acts injuriously on the heart."[1]

But it is almost impossible for disinfectants externally or internally applied, to arrest the progress of disease germs already established in the body, since, as Koch says, "before they destroy the parasite, they kill the host." He states that to check B. anthracis in man by internal treatment, 12 grammes of iodine must be constantly in circulation (see also Chapter XIII., *Internal Disinfection*).

Iodine Trichloride, ICl_3, occurs in orange-yellow needles, easily soluble, acid, and of an irritating odour, affecting the eyes. It is best kept as a 5 per cent. solution, and diluted to 1 in 1,000 as wanted; the latter strength will keep for several days in the dark, but gradually decomposes into HCl and iodic acid. Since traces of iodine favour greatly the action of Cl on organic bodies, it is probable that a small quantity of I or of ICl_3 might be an aid to chlorine disinfection. Von Langenbach, who introduced it, says that 0·67 to 1 of ICl_3 per 1,000 is as powerful as a 4 per cent. solution of phenol for sterilizing the hands and instruments. Traugott[2] used it without ill effects, the bacteria of typhoid, cholera, and diphtheria being destroyed by 1 per cent. in one minute, the two latter by 1 in 1,000 in one minute, and typhoid in five, while it was very successful on cholera dejecta. Otto Riedel[3] pronounced it to have three times the power of phenol. This is an under-estimate. My own experiments with iodine trichloride showed that with 2 parts per 100,000 B. typhosus was alive after 20 hours, but that 5 per 100,000 killed it in half an hour. Webb states that when mixed with stearine and burnt, it gives an active vapour.[4]

Iodates are disinfectant, as they easily yield oxygen and even iodine. Iodine dissolves at once in an alkali, producing a mixture of iodide and iodate, which, on the addition of an acid, liberates hydriodic and iodic acids. These acids interact on one another, setting free iodine as a precipitate if strong, or in solution if weak.

[1] *Proc. Roy. Soc.*, 1884.
[2] *Zeits. f. Hyg.*, 1893, p. 427.
[3] *Arb. Kais. Gesund.*, 1887.
[4] Reichardt, *Desinfectionsmittel*, 1881, p. 68.

Sonstadt has proposed[1] a mixture of calcium iodate and an alkaline salicylate for destroying the disease-bacteria of pleuro-pneumonia, etc., by spray or vapour. Stronger solutions are made by adding sodium or potassium citrate, which increases the solubility of the iodate. "It may be used as a lotion for sores, bites, or wounds, by injections for cholera or typhoid, or internally." Griffiths states[2] that a solution containing 0·5 per cent. of potassium iodate destroys several microbes.

Dr. J. Ruhemann (Therapist, October 15th, 1894) investigated the physiological action of iodic acid and iodates. The former in the pure state is caustic, but a solution of 0·1 to 0·5 per cent. he pronounced to be an agreeable disinfectant, styptic, and astringent gargle or lotion. For internal administration sodium iodate is alone recommended, and can be taken without danger in daily doses of 15 grains. In dilute solution, by itself, or with boric acid, it is used for injections.

Periodates have been introduced, but have not fulfilled expectations.[3]

Iodine Cyanide is said by Kobert to be universally destructive to the lower forms of life. It is difficulty soluble, very pungent, and poisonous, and is suggested for preserving biological specimens.

Organic Haloid Compounds

have nearly all some antiseptic properties, those of the aromatic series being generally more antiseptic and less anæsthetic than the alcohol group.

Chloroform, $CHCl_3$, is a strong antiseptic, but its action on animals almost confines its use to preserving medicinal infusions. It boils at 61° C., has a sp. gr. of 1·497, and is nearly insoluble in water. A 5 per cent. solution in spirit is sold as a preservative. Vallin states that to kill vigorous bacteria requires 1 per cent. of chloroform.[4] F. Bouillat[5] also obtained unsatisfactory results with CCl_4, C_2Cl_4, and C_2Cl_6.

[1] Patent No. 4,920, Oct., 1883.
[2] *Proc. Roy. Soc. Edin.*, March, 1889.
[3] Weaver, in the *Builder*, September 11th, 1839.
[4] "Traité des Désinfectants," p. 206.
[5] *Zeits. f. Prakt. Chem.*, vol. xxv., p. 300.

Bromoform, $CHBr_3$, is similar, but more expensive, less volatile, equally insoluble, and less stable.

Iodoform, CHI_3, a yellow crystalline powder of persistent and disagreeable odour,[1] volatile, soluble in alcohol, but almost insoluble in water, was introduced by Von Moorhof, of Vienna, in 1881, and is much used in hospitals for dressings, etc., in the form of iodoform gauze. A liquid containing iodoform in solution or suspension is readily made by adding to tincture of iodine strong liquor potassæ or liquor sodæ until the colour is just destroyed, and pouring this solution into a large bulk of water.

Iodoform night-lights have been already mentioned (p. 100).

To prevent the putrefaction of bronchial mucus in pulmonary diseases, Chiaramelli recommended the internal administration of iodoform. The medicine is eliminated by the lungs, hence its action would be less irritant than in direct inhalation.[2]

The United States Pharmacopœia gives the following formula for iodoform gauze:—

Iodoform	10 parts.
Ether, sp. gr. ·725	40 ,,
Alcohol, ,, ·820	40 ,,
Tincture of benzoin (1 in 5)... ...	5 ,,
Glycerine	5 ,,
Gauze muslin	A sufficient quantity.

"Dissolve the iodoform in the ether, then add the alcohol, benzoin, and glycerine; immerse in a weighed quantity of this solution the exact amount of muslin required to absorb it all, so as to make a product of the required strength in

[1] Amongst a large number of more or less inodorous and "non-poisonous" compounds proposed in its place are: Iodoformin, $C_6H_{12}N_4I_4$, a white powder easily breaking up into I and formaldehyde (*Pharm. Centralhalle*, 1895, xvi., 651 and 654, and 1897, 38, 457); Di-and tetra-iodoethylene (*Berichte*, 1897, xxx., 1200); Iodocresol, "Traumatol," Patent 5288, 1894; Di-iodomethylsalicylate, "Sanoform" (*Pharm. Zeit.*, xii., 320); and "Airol," basic bismuth-oxyiodide gallate (*Therap. Monats.*, 1896, x., 86), related to "Dermatol." Schacherl finds that iodoform gauze often contains only a fraction of the stated quantity, and gives directions for its estimation (*Apoth. Zeit.*, 1897, xii., 96). Every soldier in the German army has to carry iodoform gauze (see also Chapter XIII.).

[2] *Lyon Médical*, 1882, p. 362.

iodoform (generally 30 to 50 per cent.), dry it horizontally in a dark place. Preserve it in air-tight receptacles."

Bisulphide of carbon has been suggested as a solvent, but its odour and inflammability render it objectionable.

Iodoform is also used in fine powder for dusting wounds, in bougies with cacao butter, in emulsion of 10 to 50 per cent. with glycerine, water, and tragacanth, and in solution of 1 part iodoform with 11 of vaseline to 9 of benzene with 2 drops of oil of wintergreen for injections.

The antiseptic power of iodoform has been much disputed. While the *Lancet* asserts[1] that it is a much better antiseptic than most other substances which are used for the same purpose, and is of much more value than carbolic solution, and while Sir Joseph Lister found it of the highest value for wounds, Messrs. Hehn and Rosvinj maintain[2] that in a long series of experiments they have proved that it is not antiseptic at all, but only a desiccant. "Sterilized iodoform jelly, when inoculated with micro-organisms, was found to be full of them, all growing freely, on the third day." Riedlin asserts[3] that "as a parasiticide it is feeble and inert, but it dries the surface of wounds." Miquel in his table marks it as very strongly antiseptic[4]; but Bouillat[5] found that 10 per cent. of iodoform did not arrest putrefactive change in extract of pancreas. The truth is, as pointed out by Behring, that it produces its undoubtedly beneficial effects, not by acting directly on bacteria, but by inducing chemical changes in their toxic products. He has ascertained that some of these toxines are altered chemically by iodoform and rendered harmless.

Drs. Forster and Marchand[6] are in favour of iodoform. Dr. W. D. Miller does not recommend it for dental purposes.

Its utility must be limited to surgery, and perhaps also to fumigation in the candles already described.

Ethyl iodide is unstable and easily gives off iodine, of which it contains 81 per cent. It has proved useful in phthisis and asthma, in doses of 10 to 15 drops inhaled

[1] *Lancet*, 1887, p. 595.
[2] *Chem. News*, vol. lv., 1887.
[3] Arnould's *Hygiène*, p. 498, 1889.
[4] *Les Organismes Vivants de l'Atmosphère*, 1883, p. 289.
[5] *Zeitsch. f. praktisch. Chem.*, vol. xxv., p. 300.
[6] *Archiv. Path. Anat.*, vol. xciii., 1883.

several times a day. Iodine may be detected in the urine and saliva soon after inhalation. It possesses germicidal powers, and readily destroys *Bacillus tuberculosis*.[1] Ethyl bromide has also been suggested.[2] Their cost and low volatility would negative them as disinfectants.

Organic Compounds containing Iodine.—The halogens can only exert their disinfectant action in the free state; in combination they may modify the properties of the compound, and make it possibly more antiseptic, but they cannot be disinfectant in the sense of burning up the organisms as chlorine, bromine, and iodine in the free state do. It is true that some of these bodies are decomposed more or less slowly by light setting free some of the halogen, but this would be a protracted, expensive, and wasteful process.

Europhen (isobutyl-cresol hydriodide); iodol (tetra-iodo-pyrroline); aristol (di-iodo-di-thymol); and sozo-iodol (sodium-di-iodo-paraphenol sulphonate) have been proposed as iodoform substitutes, and will be further described among the aromatic antiseptics.

The periodides of the phenols have been patented for antiseptic use.[3]

Fluorine itself is more energetic than chlorine, but on account of the intensity of its action and the difficulty of its preparation, is not likely to be made available.

Many years ago William Thompson found that hydrofluoric acid, fluorides (acid or neutral), and silicofluorides (fluosilicates) were antiseptic. He patented their use under the name of "Salufer." Sodium silicofluoride is a powder possessing no smell and only a slight saline taste, and is sparingly soluble in water. A saturated solution contains 0·61 per cent. of the salt, and is not irritating to wounds. Thompson states that it is stronger than a 1 per 1,000 solution of mercuric chloride, and not poisonous. It is commonly sold in cubes of a definite weight, being thus more easily carried. One cube dissolved in a quart of water is suitable for washing the hands. It is highly spoken of as a non-toxic antiseptic and deodorant. A "Salufer" wool is also made.[4]

[1] Griffith's *Micro-organisms*, p. 208.
[2] Sormani, *Atti dell'Inst. Lombardo*, 1887.
[3] Bayer of Elberfeld, and Willcox, Patent No. 7,782, 1892.
[4] *Chem. News*, vol. lvi., p. 132.

Arthus later studied the action of sodium fluoride on various ferments, and stated that butyric fermentation was completely inhibited by 0·4 per cent. of the salt, and that milk 0·3 per cent. would keep indefinitely.

Teisler's patent, 8,524 of 1901, for preserving eggs by fluosilicic acid or its salts, is vitiated by the fact that an insoluble compound would be formed with the lime of the shell. It does not seem to have been noticed that this precipitation by lime stands in the way of the use of fluorine compounds for many of these purposes.

The work of Dr. Effront on the use of mineral acids for the suppression of undesirable fermentations in breweries and distilleries, has demonstrated that hydrofluoric acid has a powerful antiseptic action, and protects the wort from lactic and butyric fermentations. The ammonium and potassium salts have also been used successfully in this way. All the fluorides appear to possess the further remarkable property of increasing the diastatic power of malt.[1]

Dr. Griffiths in several experiments has found that a 0·4 per cent. solution of sodium silicofluoride was fatal to the bacteria tried—viz., *Micrococcus prodigiosus* and *Bacillus œdematis maligni*.[2]

Fluoborates have been proposed as antiseptics[3] and Melikoff has discovered oxidizing compounds called *fluoperborates*, formed by union with hydrogen peroxide.[4]

The free acid, and the fluorides of potassium, sodium, ammonium and aluminium, are prepared on a considerable scale, specially free from arsenic, for the brewing and distilling trades, by Merck of Darmstadt. Cluss[5] fixes the best proportion of HF for spirit distilling at 8 to 10 grammes (120 to 150 grams.), and that of NaF at 10 to 15 grammes, per hectolitre of mash (22 gallons). Cluss and Feber[6] obtained good results by the addition of aluminium fluoride, 33 grm. per hectolitre of the ferment. Two per cent. more alcohol is said to be produced by the use of fluorides than by any other antiseptic, such as sulphurous acid, but it is

[1] *Monit. Scient.*, vol. vi., 1892, p. 81.
[2] *Proc. Roy. Soc. Edin.*, vol. xv., p. 37.
[3] Patent 2,277, of 1899, is a complex mixture containing them.
[4] *Berichte*, 1899, xxxii, 3510.
[5] *Zeits. f. Spiritus-Industrie*, 1894, p. 241, and 1895, p. 166.
[6] *Ibid*, 1898, p. 2.

essential for the full development of the action of the fluoride that the yeast mash and bulk mash should be acted upon at the same time. "Its employment ensures, even when the original growth happens to be sparing or weak, the possession of a uniformly good yeast which is not subject to deterioration through the presence of obnoxious organisms and, in a measure, behaves like a pure culture. The acidulation of the yeast is almost entirely avoided by fluoric acid." In the form of a dry powder fluoride of sodium has the advantage over the fluid preparation of being more easily shipped and worked. The preparation of yeast is greatly simplified by the use of fluoric acid as shown by Effront.[1] Five litres (about 1 gall.) of sweet mash are taken per 100 litres of the total mash and the whole is treated at 30° C. with the requisite quantity of fluoric acid. (This quantity, say 5, 8, 12, 15 grm., must be determined experimentally). After adding 1 litre of the mother yeast, the whole should be subjected to warm forced fermentation until the following day, when the yeast will be ready for the next day. It is not necessary to mash with malt, and there is no need to rigorously maintain the temperature of the yeast mass at 56° C., nor to cool down to 40° C. exactly, in order to produce lactic acid fermentation, since the latter is superfluous, inasmuch as the lactic acid is replaced by fluoric acid. The addition of malt is likewise superfluous. It is said to be advantageous to rinse the mashing vats with water containing fluoric acid. The addition of 2 grm. (grs. 30) per hectolitre ($3\frac{2}{3}$ cub. ft.), of purified ammonic fluoride free from arsenic has been recommended as an excellent substitute for pasteurization, so as to obviate after-fermentation, or to keep bottled export beer clear.

According to the investigations of Marpmann,[2] the fluorides are excellent antiseptics and as such largely used in microscopy. A 2 per cent solution of fluoride of sodium preserves completely anatomical preparations and fluids, pieces of animal flesh, etc., and is said to be less apt to produce changes in the morphological structure than solutions

[1] *Moniteur scientifique*, 1890, p. 449 and p. 790, *Zeitschrift für Spiritus-Industrie*, 1896, p. 183, and as above.

[2] *Zeitschr. für angewandte Mikroskopie*, 1899, p. 33; *Centralblatt für Bakteriologie*, 1899, xxv., 309.

of formaldehyde, mercuric chloride, or bichromate. Stronger solutions of 3 to 5 per cent. are required to arrest putrefaction in animal substances which have already passed into a state of decomposition. The action of fluorides on micro-organisms seems to be physiological rather than chemical, since they do not act by coagulating albuminoids, nor do they destroy life by chemically changing the protoplasm or forming compounds with the cellular tissue, as is the case with mercuric chloride, phenol, or formaldehyde. Favourable reports are given of the use of the fluorides by botanists and biologists, who employ them as fixing and preserving agents. A 0·7 per cent. aqueous solution of fluoride of sodium may be used in the place of Pacini's fluid for the examination of blood preparations. The double advantage is claimed that the blood corpuscles are left morphologically intact while the blood is protected for a few days from putrefaction. A decidedly higher antiseptic power than that of fluoride of sodium is possessed by the bifluoride, NaF, HF. This is a white salt possessing an acid reaction and capable of corroding glass, as a 2 per cent. of sodium bifluoride is available for etching glass without any further addition. Marpmann[1] includes bifluoride of sodium among the best antiseptics. Dilute solutions are not directly poisonous and are therefore pleasanter to work with than formaldehyde and sublimate. Its solution is colourless and is not apt to become cloudy or undergo precipitation; it also changes the colour of specimens very slightly and acts indifferently upon solutions of gelatine.

Marpmann recommends the following solution for fixing lower organisms: sodic fluoride 0·5 part, sodic bifluoride 2 parts, water 100 parts.

Animal tissues are fixed by a 5 per cent. aqueous solution of the bifluoride. Reptiles and frogs retain their colours beautifully in the following solution: sodic bifluoride 5 parts, glycerine 50 parts, alcohol 100 parts, water 400 parts. Anatomical specimens may be kept in an aqueous 10 per cent. solution of chloride of sodium containing 1·65 per cent. of sodium bifluoride. Glands and brain substance are hardened within three or four days by a mixture of equal parts of Müller's fluid and water to which are added 5 per cent.

[1] *Zeitschr. für angew. Mikrosk.*, 1899, p. 33.

sodium bifluoride and 5 per cent. of a 40 per cent. solution of formaldehyde.

Ammonium fluoride has been recommended by Baudoin and Robin in doses of 0·05 gramme as a gastric antiseptic.

With reference to the effect on health of fluorides as food preservatives, experiments were made by Perret,[1] who ate daily for three weeks butter preserved with a solution of sodium fluoride (0·3 per cent.), using it in the regular way, both at the table and in cooking. It has no unusual taste, and he was not sensible of any unfavourable influence, digestive or otherwise. He gives as his opinion that sodium fluoride is preferable to salt. It may be worth while mentioning that the same view has been advanced with regard to boric acid, which is now being much used as a butter preservative. Perret's conclusions are as follows:—

1. Sodium fluoride is not actively toxic, even when a saturated solution is taken into the stomach.

2. It is not toxic when given subcutaneously in doses not over one-ten-thousandth of the weight of the animal.

3. A solution of 0·3 per cent. will arrest the development of all the microbes which cause the rancidity of butter. Butter preserved by the solution can be entirely freed from the sodium fluoride by careful washing in a stream of water.

4. From this it would appear that the article should be permitted as a food preservative.

Concerning the action of sodium fluoride upon the ordinary digestive agents, the following experiments were performed for the Pennsylvania Department of Agriculture:

A starch solution containing 10 grammes of arrow-root starch in 1 litre of water was used, and portions of 50 cubic centimetres taken for each experiment. Diastase, taka-diastase, papaw ferment, and pancreatic extract were used, and small amounts of sodium fluoride added to the liquid. The experiments showed that considerable amounts of sodium fluoride do not interfere with the action of diastase, taka-diastase, nor papaw ferment, but that pancreatic extract is very sensitive to it. Ten milligrammes of sodium fluoride to 50 cubic centimetres of the starch solution prevented the digestive action of a quantity of pancreatic

[1] *Public Health*, Oct. 1898.

extract that, in the absence of the antiseptic, would have rapidly converted the whole of the starch into sugar and dextrin.

Otto Hehner,[1] in a paper recording his method of testing for fluorides, and the fact that he had discovered them in 20 butters sold in London, 10 of which also contained boric, is of opinion, from a series of diet experiments, that the use of fluorides in articles of food should be strongly discouraged.

H. B. Baldwin[2] describes two cases of poisoning by sodium fluoride, which had been accidentally used instead of baking powder. In the fatal cases the dose was estimated to have been 9 to 10 grammes. The observation is doubtful, as this amount is over a teaspoonful. He states that 0·25 gramme produced in himself, nausea in two minutes, which increased in intensity for 20 minutes, and did not disappear until the second day.

CHAPTER V.

THE NON-METALLIC ELEMENTS AND THEIR DERIVATIVES.

(continued).

OXYGEN AND OZONE: Ozonisers—Peroxide of Hydrogen—Sodium peroxide—NITRIC ACID AND OXIDES OF NITROGEN: Nitrous Ether—SULPHUR AND ITS COMPOUNDS: Sulphuretted Hydrogen—Sulphurous Acid—Sulphites and Bisulphites—Thiocamf—Sulphites in Food—Sulphuric Acid—Sulphates—Bisulphide of Carbon—BORIC ACID: Borax and other Borates—Boroglyceride—Boric Acid in Food—Physiological Effects—INFLUENCE OF GASES ON PUTREFACTION.

OXYGEN, OZONE, AND PEROXIDE OF HYDROGEN.

OXYGEN is the chief and natural disinfectant, burning up gradually all organic substances into carbonic acid and water. This process, called decay, affects the various bodies very differently; the more putrescent compounds are generally the most rapidly destroyed, so that fresh air would be all that is needed to keep our surroundings healthy, if it were possible to ensure that all matter likely to be a source of contagion

[1] *Analyst*, 1902, xxvii, p. 173.
[2] *J. Amer. Chem. Soc.*, 1899, xxi, 517.

were liberally supplied with the oxygen of the air. The oxidation of the products of those micro-organisms which are poisonous to man, such as the "ptomaines" and "toxines," which Selmi was the first to investigate, is no easy task. The bacteria which produce these toxic compounds have a higher vitality than man, and most strong chemical agents which can kill bacteria have also a toxic effect upon more complex organisms. No man can endure an atmosphere that will kill these bacteria. Only the halogens, chlorine, bromine, and iodine can ordinarily penetrate their envelopes, and these cannot be given in sufficient quantity when man is present. It is, therefore, absolutely necessary to remove patients and seal rooms in order that disinfection may be successfully accomplished.

The importance of the distinction between an antiseptic, which simply stupefies the germs of disease for a time, and a disinfectant, which kills them and leaves the room sterile, cannot be too strongly insisted upon. The use of antiseptics merely puts off the era of putrefaction, and while arresting temporarily the evil, does not eradicate it.

The "molecular" or ordinary oxygen of the air acts slowly. When liberated from various chemical compounds, like permanganate and peroxide of hydrogen, it is said to be in a "nascent" or atomic condition, and is then far more active.

A number of inventions attempt to increase the power of atmospheric oxygen by mechanical means. Thus it has been proposed to compress the oxygen into water, increasing the solubility, and therefore presumably the activity.[1] Similarly J. Konig, with a view to increase the rate of atmospheric oxidation of the waste water of tanneries and slaughter-houses, produces a flow over a tinned iron net 4·5 metres high, with a breadth of 1 metre for every 12 litres per minute, giving as the result of an experiment:—

	Per Litre.	
	Before.	After.
Oxygen	3 c.c.	9 c.c.
Sulphuretted Hydrogen	20·4 milligrms.	0·9 milligrms.
Sulphuric Acid...	48·6 "	7·2 "

[1] E. Scruby, Patent No. 5330, 1891.

proving that strong oxidation had taken place.[1] On the same principle polluted water flowing over weirs and waterfalls is oxidized and improved in character. Organisms, however, are only partially removed by such aëration, and may set up changes again lower down.

In the self-purification of rivers in this way the natural aeration is aided by water-bacteria, infusoria and vegetation in removing most of the dead organic matter.[2]

Ozone, O_3. This allotropic modification of oxygen is produced by atmospheric electrical disturbances and in the course of many natural slow oxidations (see page 288), and is present in country air, but generally absent in the air of towns, being soon consumed, owing to its own energetic oxidizing action, by the various aerial impurities. It much resembles chlorine in chemical activity. Since the time when it was discovered that ordinary atmospheric oxygen was so easily ozonised by the silent electric discharge, a large number of inventors have suggested electrical means of this character for disinfection.

Hagen[3] instead of ozonising air, proposed to obtain a more energetic product by subjecting pure oxygen to the silent discharge, and passing it over infected articles or into sewage, when the ozone, O_3, decomposes into O_2 (ordinary or "molecular" oxygen), and the atom of "nascent" oxygen, which acts upon the organic matter more rapidly than when in the ordinary molecular condition. The remaining ordinary oxygen, mixed with a little carbonic acid, derived from the oxidation of organic matters, was carried back and ozonised again. The process was, therefore, a continuous one, the carbonic acid being absorbed by lime. It must, however, be borne in mind that:—

1. *Ozonisers do not raise the percentage of ozone to more than* 10, and generally not over 1 or 2, and this strength is hardly sufficient for sewage. It is well known that, owing to diffusion laws, a gas acts far less actively when mixed with a large quantity of another inert gas.

[1] *Chem. Zeitung*, vol. viii., pp. 56, 1008.

[2] *Journ. Soc. Chem. Industry*, 1891, p. 720; *Report of State B. of Health, Mass., U.S.A.*, p. 783; *Proc. Inst. Civ. Engineers*, 105, vol. iii., p. 9; J. Konig, *Zeits. f. Untersuch. Nahr. u. Genuss.*, 1900, 377; Rideal's *Sewage*, 1901, and *Water and its Purification*, 1902.

[3] Brin, October, 1881, patent void.

2. *A large volume of gas would be required.* An ordinary sewage containing 50 grammes of organic matter per 100 litres (50 pts. per 100,000) would require about 10 grms. of "nascent" oxygen or 30 grms., equal to nearly 15 litres, of ozone. Assuming the ozonised oxygen to contain 5 per cent. of ozone, 300 litres would be required to oxidize 100 litres of sewage if the ozone all acted, and more if, as commonly happens, only a portion were absorbed. Hence it is far too expensive for crude sewage. Its use for sterilizing water, or effluents from which a large portion of the organic matter has been removed by chemical or bacterial treatment, will be further described in Chapter XII.

3. *It comes in competition with chlorine,* which is more soluble, and therefore, more rapidly absorbed, and can be easily produced in a pure state, or 100 per cent. as against 5 per cent.

4. The increase in the amount of ozone by employing oxygen instead of air, is not sufficient to justify such a course from the economic standpoint.[1]

J. T. Wood[2] converted sewage or other polluted liquid into spray by the action of a blast of "air, oxygen, ozone, or other suitable gas" under pressure, by which it takes up more than it would under ordinary circumstances. "Any chemical precipitant" is projected into the spray, the sewage allowed to settle in tanks, and the clear liquid further purified by passing it over "oxidizing stairs," the "risers" being provided with openings which communicate with tubes containing the ozonised air under pressure. Modifications of the air-blast are described applicable to filter-beds and the weirs of rivers. This may be called a "thorough" process, but the expense would be prohibitive, and it does not appear to have been ever tried on a large scale.

A process on a similar principle for the sterilization of liquids and receptacles is described in Otto's patent 15,151, 1898. He mentions that the action of the ozone on the putrescible matters is accompanied by the production of a

[1] *Bull. Acad. Roy. Belg.*, 1901, 612. Shenstone found (*Trans. Chem. Soc.*, 1898, 248) that the proportion of oxygen converted into ozone was greater in air than in pure oxygen.

[2] Patent No. 22,747, 1891.

phosphorescent light. W. Saint-Martin states that the forcible discharge of liquids through "atomizer jets" into air or oxygen "produces a certain amount of electricity, ozonising some of the oxygen, and effecting purification by oxidation" (French patent 322,654, 1902).

In the dry state, ozone has very little action on micro-organisms; for this reason it does not act powerfully on bacilli in air.[1] When moist, however, it is a very powerful bactericide. According to Mailfert (*Comptes rendus*, cxix., 951), water dissolves about half its volume of ozone at 12° C.: he suggests the use of the saturated solution as a disinfectant. But the percentage of ozone by weight is only 0·107, and the active atom of oxygen is only one third of this, so that it would require 10 litres to give 3·6 grammes of active oxygen.

Since no materials, except glass or stoneware, resist the action of ozone, metals, wood, grease, indiarubber, etc., must be avoided in the construction of any apparatus employed.

Statements as to the best conditions for ozonisation are very numerous but show great discrepancies, owing to (1) the difficulty of carrying out in manufacturing practice the precautions possible in small scale experiments; (2) the fact that the production of ozone is a reversible action, in which ozonising and de-ozonising effects occur; (3) the subject being surrounded by so many patents. It is admitted that the heat must be prevented from rising unduly, or the ozone already formed will be decomposed. Warburg[2] obtained under similar conditions, except temperature, the following percentages of ozone: 5·74 at −71° C., 4·19 at 0°, 3·53 at 17°, 2·22 at 50°, 1·23 at 93°; agreeing with the experience in laboratories that a larger amount was yielded at low temperatures for the same electrical energy; and Siemens' apparatus is water-cooled. Some commercial generators, however, are not refrigerated, such as the Yarnold.[3] But in a later patent, 19,393 of 1900, Yarnold, junior, adopts water cooling, "to avoid loss of efficiency

[1] O. Fröhlich, *Ber. Deutsch. Elektrochem. Ges.*, 1894, 30.

[2] *Sitz. Akad. Wiss. Berlin*, 1900, 712.

[3] Engledue, *J. Soc. Chem. Ind.*, 1898, 1101.

incidental to rise of temperature." Baron Tindal asserts, in a description of his apparatus[1], that better manufacturing results are obtained if cooling of the gases be disregarded, and care only be taken that the ozonised gas passes through an extended, even, and dense discharging field.

As to moisture, Shenstone, in careful laboratory experiments (loc. cit.), found that dry air was more difficult to ozonise than moist, and that the product was less stable. In the former case he succeeded in converting 67 per cent. of the oxygen, as against 98 per cent. in the latter, equal to 14·1 and 20·6 per cent., respectively, of ozone in the resulting ozonised air. Both results are much higher than are commercially obtained. On the other hand in nearly all the manufacturing plants the air is directed to be first dried, sometimes with quicklime (Yarnold), or concentrated sulphuric acid. All agree that the air should be freed from dust, which uses up ozone on becoming moistened, and also is liable to form points for sparking. Numerous investigations have been conducted by Chassy[2] and others. Arnold and Mentzel[3] give details of the best methods of preparing ozone by the electric discharge, by phosphorus, and by the action of H_2SO_4 on permanganate, persulphate, or barium and hydrogen peroxides.

When permanganates are treated with strong sulphuric acid, ozone is evolved. Meyer[4] makes an intimate mixture of barium permanganate and sodium bisulphate in the proportion of 25 per cent. of the former and 16 per cent. of the latter. "If sufficient water be added to such a mixture so as to form a thick syrup, ozonised oxygen will be evolved." Donovan and Gardner electrolyse a saturated solution of potassium permanganate in 5 or 10 per cent. sulphuric acid, and claim that the liberated oxygen contains 38½ per cent. of ozone.[5]

The cheapest way of obtaining ozonised air is by means

[1] English patent 24,548, 1898.

[2] *Comptes rend.*, 1900-1903; Otto (*Ann. Chem Phys.*, xiii. 77; *Mem. Soc. Ing. Civ. de France*, 1900, 149); Ladenburg (*Berichte*, 1901 etc); Warburg (*Sitz. Akad. Wiss. Berlin*, 1900-1901); Shenstone, *Trans. Chem. Soc.*, 1897, 1898).

[3] *Berichte*, 1902, xxxv., 2902.

[4] Patent No. 16,463, 1888.

[5] Patent 19,127, 1894.

of the silent electric discharge. A convenient method, however, for generating it in small quantities is by means of moist phosphorus, keeping it constantly cool to avoid inflammation.

A. Riche first proposed moistening the phosphorus with a solution of potassium bichromate and sulphuric acid, instead of water, and aspirating or, better, driving a slow current of air over it. He mentions a form of "kerite" as the best material for the tubes.

Poulsen[1] and Kattenhoy[2] place the sticks of phosphorus in glass-capped holders, just projecting from a solution of potassium permanganate in 10 per cent. sulphuric acid. The whole is enclosed under a bell-jar pierced with holes for the outlet of ozonised air, with a locked cover to prevent tampering. There is a funnel to add more liquid when required, and a sliding glass-rod support to adjust the level of the phosphorus. Such an apparatus might be of service for inlet ventilators, but its use would not be advisable in a room, since even a trace of ozone in excess would be irritating to the lungs.

At Berlin the electrical manufacture of ozone on a large scale has been applied to sanitary purposes.

Andreoli's apparatus, at present in operation at Allen & Hanbury's works at Bethnal Green, is based upon the silent discharge of electricity from points in the well-known "brush" or glow, as distinguished from the spark. The former generates ozone, whereas the latter, by its high temperature destroys it. A large number of serrated strips of tinned iron or aluminium are arranged parallel to one another so as to form gratings on opposite sides of plates of glass. The gratings are connected with the poles of a dynamo-transformer, giving a high-tension current of 10,000 volts. The apparatus gives a larger surface and a more uniform distribution of the current than other ozonisers of the Siemens' type. Air is driven by a fan through a cotton wool filter at a rate of 160 cubic feet per minute, then, after cooling, and drying by sulphuric acid on pumice, it passes over the gratings by which about 6 per cent. is calculated to be ozonised.

[1] Patent 14,862, 1892.
[2] Patent 24,709, 1893.

The same inventor has smaller open ozonisers intended for domestic use, which can be worked by an electric supply current.[1]

Ozonised air under pressure, alternately with steam, has been used successfully for destroying bacteria and moulds in brewers' foul casks, known as "stinkers," and for render-them sweet.[2] Kropf patented the introduction of ozonised air into wort during the latter part of the fermentation to ripen it and "to destroy all noxious germs."[3]

Dr. Foster, of Berlin, proposes the supply of a small quantity of ozone to the air of towns, stating that many epidemics, such as influenza, arise at times when the atmospheric ozone is at its lowest, and that an artificial supply might prevent or modify the outbreaks.

Many years ago an attempt was made to supplement the advantages to be derived from a winter's sojourn in the High Alps by supplying the air of the hotel at Maloja with ozone from powerful induction coils, but it seems that no special benefit from its use was felt by the patients. Dr. Hassall's experience at his sanatorium at San Remo was also disappointing. There are, however, many cases in which it is stated to have proved beneficial in phthisis, and late experiments in the Berlin hospitals have shown results in its favour. An apparatus by Dr. Costau of Paris, for charging air with menthol and then ozonising it, is reported to have had good effects in the consumptive ward of the Boucicaut and other hospitals in France, and is undergoing trial at the London Hospital.

Spranger[4] passed ozone into essential oils, especially oil of citron, either pure or diluted with alcohol, in order to obtain permanent ozone solutions of definite strengths. For medicinal purposes a 60 per cent. alcohol is used, containing 0·5 per cent. of citron oil. Ozone is passed into this solution until saturated, and for use 40 drops are recommended to be taken in water as an antiseptic remedy. (See further under Terpenes, Chapter X.). A later patent,[5] prepares solutions by saturating ethyl aldehyde with ozone.

[1] *Industries and Iron*, Aug. 18, 1893.
[2] *J. Soc. Chem. Ind.*, Dec. 31st, 1898.
[3] No. 22,355, 1898.
[4] Patent 18,924, 1896.
[5] No. 4,153 of 1902.

Peroxide of Hydrogen, H_2O_2, is prepared by acting on a peroxide of an alkaline earth by an acid, *e.g.*:—

$$BaO_2 + CO_2 + H_2O = BaCO_3 + H_2O_2$$
$$BaO_2 + H_2SO_4 \text{ (dilute)} = BaSO_4 + H_2O_2$$

It is a syrupy, inodorous, and neutral liquid, which easily decomposes into water and nascent oxygen, hence bleaches and acts as a powerful oxidizing agent. In the dilute state it is neither irritant nor poisonous. Its instability is lessened by the addition of a small quantity of acid. Two forms occur in commerce—"ten volumes" and "twenty volumes"—indicating nominally the number of times its volume of oxygen it gives off when treated with peroxide of manganese, according to the following equation--

$$H_2O_2 = H_2O + O$$

By careful evaporation it may be further concentrated, and is even said to have been obtained in crystals,[1] but in these forms it becomes liable to explosion.

The commercial peroxide should always be tested as its quality is often very inferior.[2]

When an electric current is passed through water, whether the gases oxygen and hydrogen be evolved, or whether the current be so weak that the oxygen remains dissolved, the latter is ozonised, and the water acquires oxidising properties, and behaves as if it contained peroxide of hydrogen. Such a solution has been patented, but the product is too weak to be of use. "Ozonised water" has been introduced under the name of "antibacterikon" (see p. 114).

Peroxide of hydrogen is probably present in the "Hermite" solution already described (p. 90).

As a disinfectant hydrogen peroxide would be excellent if it were quicker in its action. Angus Smith in 1869 called it "the disinfectant of the future." It oxidizes such bodies as sulphuretted hydrogen readily, it has no smell of its own, and is not poisonous. Metals and fabrics are not attacked; it has not, like permanganate, the tendency to act on inert

[1] *Moniteur Scientifique*, Aug., 1902.

[2] For a simple method of measuring the gas evolved, see *Methods of Analysis*, Chap. xvi.; also as to impurities and methods of testing, P. Sisley, *Rev. Gén. des Mat. Colorantes*, 1901, 209.

matter, though it possesses the true characters of a disinfectant. Its action has been recently studied in some detail by MM. Paul Bert and Reynard.[1] They found that all fermentations caused by bacteria are at once stopped by peroxide of hydrogen, and the ferment killed; while no effect is produced on enzymes such as diastase and those of saliva, gastric juice, and the pancreas. When fibrin has been dissolved in dilute hydrochloric acid, or changed into fibrin-peptone by artificial digestion, hydrogen peroxide is without action on it. It has no effect on foods, like albumen, casein, milk, eggs, fats, sugar, starch, and juice of fruits. So that it is practically one of the few disinfectants which have no effect on digestion, and yet prevent the interfering action of organisms.

Van Tromp[2] asserted that 1 part of peroxide of hydrogen in 10,000 of polluted water, when shaken up and allowed to stand for twenty-four hours, was usually sufficient to sterilize a water. Altehoefer, however, found[3] that to ensure sterility, it was advisable to use larger quantities, namely 1 part in 1,000 parts of water. "Experiments made with waters purposely infected with cholera and typhoid bacilli, showed that both these were destroyed in twenty-four hours by 1 per mille of hydrogen peroxide." Altehoefer, beyond a slight taste, which disappeared after twenty-four hours, found no detriment to the water for drinking or domestic purposes, and recommends its application for household use as a protective measure during any epidemics of typhoid fever or cholera. He suggests that 10 c.c. of a 10 per cent. solution should be added to a litre of water, or 700 grains of this to the gallon. Traugott testifies to its innocuous character, even when swallowed in large doses.[4]

Guttmann injected peroxide of hydrogen hypodermically, but the oxygen was liberated as gas in the circulation, and the animals died of asphyxia. Paneth[5] found that it was a violent poison to many lower forms of animal life: all

[1] *Berlin Ber.*, vol. xv., p. 1,585.
[2] *Apoth. Zeitung*, 1890, p. 485.
[3] *Centr. f. Bakteriol.*, 1890, vol. viii, p 129.
[4] See under *Light*, p. 10.
[5] *Chem. Centralblatt*, 1890.

ciliate infusoria (some of which occasion bad tastes and odours in water) were killed by 1 of H_2O_2 in 10,000.

Miquel places it at the head of his list of antiseptics, making 0·05 grm. sufficient to sterilize 1 litre of beef tea as against 0·07 grm. of mercuric chloride. Later observers give it much lower potency, averaging about 0·1 per cent. As to the use of ozone and hydrogen peroxide for sterilizing waters and foods, see Chapters XII. and XIV.

The class of oxides known as peroxides, which contain more oxygen than the ordinary bases, resemble hydrogen peroxide, and are capable of the following reactions:—

1. When heated they give off oxygen —

$$H_2O_2 = H_2O + O.$$
$$BaO_2 = BaO + O.$$

2. With hydrochloric acid they generate chlorine—

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

3. With sulphuric acid they give (ozonised) oxygen or hydrogen peroxide—

(i.) Strong acid: $BaO_2 + H_2SO_4 = BaSO_4 + H_2O + O.$

(ii.) Dilute acid: $BaO_2 + H_2SO_4 = BaSO_4 + H_2O_2.$

Many of the peroxides have consequently received attention in the search for disinfectants, and organic bodies of this class, especially acetyl-hydrogen peroxide, CH_3COOOH, are the subject of Page's French patent, 319,248, of 1902.

Sodium Peroxide, Na_2O_2, is a yellowish white powder which on exposure to air becomes damp and spoils, therefore must be kept in tightly closed tins. It is easily soluble in water, and acts like a solution of hydrogen peroxide *plus* caustic soda.

$$Na_2O_2 + 2H_2O = 2NaOH + H_2O_2.$$

If acid be added to the powder, hydrogen dioxide or ozonised oxygen is produced, according as the acid is weak or strong.

Jacobsen[1] mixed "dioxide of barium, strontium, or calcium with any desired metallic salt." Peroxide of barium is cheaply obtained in Brin's oxygen process. Carbonic acid of the air, in the presence of water, causes it to yield peroxide of hydrogen.

[1] Patent No. 1,711, 1882.

Blatz proposed to add to water citric acid and then sodium peroxide in the proportion of 420 to 234, giving hydrogen peroxide and citrate of soda, and states that with 1 in 1,000 of Na_2O_2, water containing many bacteria is sterilized in 24 hours, cholera bacilli are killed in 3 hours, and typhoid in 6. He observes that the resulting liquid is innocuous and not injured in taste or odour, but estimates the cost of *materials* at 3 pfennige per litre, or about $1\frac{3}{4}$d. per gallon, which is of course prohibitive on the large scale.[1]

Schone is of opinion that peroxide of hydrogen exists naturally in the atmosphere and in waters. The point is not yet proved.[2]

Dr. Richardson proposes to saturate peroxide of hydrogen with iodine (very little dissolves), then to add $2\frac{1}{2}$ per cent. of sea salt, and to use the mixture as an antiseptic spray in an "atomiser."

According to Budde's process for sterilizing alimentary substances at low temperatures,[3] solid foods may be sterilized by soaking in water containing hydrogen peroxide, and heating to a temperature not exceeding 50° C. The substances are stored in closed vessels containing the peroxide. Liquids are mixed with a certain quantity of hydrogen peroxide and kept in ordinary syphons. On heating, the peroxide gives off oxygen with sufficient pressure to empty the syphon when the contents are required for use.

Both hydrogen and sodium peroxide combine with various bodies to form compounds which have disinfectant properties and in some cases are crystalline. S. Tanatar[4] has obtained in crystals KF, H_2O_2; Na_2SO_4, 9 H_2O, H_2O_2; and $NaNO_3$, Na_2O_2, 8 H_2O; the first is fairly stable, the last is easily decomposed. But the manner of their preparation is expensive.

Peroxide of hydrogen and ozone with other products are formed by the slow oxidation of essential oils in presence of air and water, especially if warmed. Such a product, consisting of turpentine oil, water, and air, was patented[5] under

[1] *Apoth. Zeit*, 1898, xiii, 728.
[2] *Chem. News*, April 27, 1894.
[3] English patent 10,903 of 1903.
[4] *Chem. Zeit.*, 1901, xxv. [92], Rep. 326.
[5] Patent No. 274, 1878.

the name of "Sanitas"; more recently[1] resin, resin oil, camphor, and thymol have been added. These antiseptics would supplement the action of the peroxide of hydrogen or ozone that might be present (see Chapter X.).

J. Y. Johnson[2] causes air or oxygen to pass through a mixture of 9 parts of water and 1 part of spirit of turpentine, maintained at the ordinary temperature. When sufficiently saturated with ozone, it is used as a disinfectant for washing wounds.

A convenient test for the presence of peroxide of hydrogen is to add a drop of potassium bichromate solution and a little dilute sulphuric acid to the disinfectant. A blue colour is produced on shaking with ether. "Sanitas" answers to this test when freshly prepared.

Nitric Acid and Oxides of Nitrogen.

Nitric Acid, HNO_3, as one of the strongest of oxidizing agents, is actively disinfectant, but also very corrosive and poisonous. It oxidizes organic matters to such compounds as oxalic acid, and then finally to carbonic acid and water, being itself reduced successively to the lower oxides of nitrogen, which in turn combine with the organic substances to form nitro-derivatives like pyroxylin, nitroglycerin, and picric acid. The latter class of bodies, when soluble or volatile, are themselves poisonous and disinfectant.

Nearly all metals are attacked by the acid, giving nitrates and oxides of nitrogen. Nitric acid vapours are white, and are much less injurious than the red vapours of the oxides. Nitric oxide, NO, is colourless, but turns red in air, forming higher oxides according to the quantity of oxygen; all these are exceedingly poisonous, since they form compounds with the colouring matter of the blood. They may be described as irritant, depressant, and narcotic.

Nitric acid in dilute solution acts similarly and is about equal in power to hydrochloric (p. 96).

Nitric acid fumigation was introduced in 1780 by Dr. J.

[1] Patent No. 1,172, 1882

[2] Patent No. 14,864, 1884.

C. Smith for a violent outbreak of typhoid in the British Fleet. For his success he was voted £5,000. On a large iron sand-bath over a brazier were placed a number of stone-ware capsules, each containing 12 grammes of oil of vitriol; when hot enough, powdered nitre was added little by little. On stirring with a glass rod, the nitric vapours were evolved in abundance as a thick white mist. The apparatus was carried about among the patients, who unfortunately were affected with violent coughing. Severe bronchial irritation followed, and some destructive action of the surroundings. 350 grammes of nitre in 27 capsules were used for the one hospital ship. The fumigation was daily repeated for a week. The heat should not be too great, and the disengagement should be gradual. The horrible stench at once disappeared, and the epidemic was conquered in three weeks, the deaths falling on the first day from 31 to 9, and then steadily to the end.[1]

Nitrogen Trioxide, N_2O_3, is a red gas of suffocating odour, combining with water to form nitrous acid, HNO_2. Girard and Pabst[2] describe N_2O_3 as a very strong disinfectant in doses so weak as to be not dangerous, "the odour being rather aromatic and etherial." Unfortunately, nitrogen trioxide is a very unstable substance, and is almost always accompanied by the other oxides of nitrogen. The above-named authors patented the use of "chamber-crystals," or nitro-sulphuric acid, in a tower filled with coke. The putrid emanations from closets or sewers are caused to pass up this tower, and, being moist they dilute and decompose the chamber-crystals, which evolve this gas—

$$2SO_2(NO_2)OH + H_2O = 2H_2SO_4 + N_2O_3.$$

The gases on passing out are quite innocuous.[3]

Haddan[4] mixes an aqueous solution of sodium or other soluble nitrite with sulphuric acid (5 parts of acid in 1,000 parts of water), and adds the resulting dilute nitrous acid to sewage. The nitrogen trioxide transfers oxygen to the organic matter, and is re-oxidized by the air, so acting in

[1] Vallin, *Désinfectants*, 1882, p. 265.
[2] *Désinfection des Latrines*, 1881.
[3] Patent No. 18,486, 1881.
[4] Patent No. 4,714, 1885.

the well-known way as a carrier from the atmosphere to the sewage, so that "all organisms are destroyed." Although theoretically this action enables a small quantity of oxide of nitrogen to do an unlimited amount of work, yet in practice the disinfection by nitrous compounds has proved expensive, and has no advantages over other methods.

Nitrites are somewhat antiseptic; internally they are dangerous (*Lauder Brunton*).

Nitric Peroxide, NO_2, is a red irritant gas, easily condensed to a brown liquid. If it were desirable, the latter would be the most convenient form for use, and could be obtained in sealed tubes or syphons like sulphurous acid. It is made by heating nitrate of lead.

$$Pb(NO_3)_2 = PbO + 2NO_2 + O.$$

Guyton de Morveau, in his classical work, found that this gas was a feeble disinfectant, but irrespirable and dangerous. Payen[1] placed NO_2 in the front rank among disinfectants. He used for a space of 40 cubic metres, 1,500 grammes of nitric acid, 2,000 of water, and 300 of copper turnings tied up in a thick paper bag to moderate the action. Even thus it is liable to become too violent, and much of the nitric acid is wasted as nitrous oxide or even nitrogen. Three-fourths of the nitric acid remain behind as cupric nitrate, and this, of course, would act slowly as a liquid absorbent. Payen's process was carried out in sealed rooms during the siege of Paris. He allowed forty-eight hours for complete disinfection. The cost is obviously very high.

Notter[2] says that an atmosphere containing 0·35 per cent. of nitrogen peroxide killed all bacteria in putrid beef tea in forty-eight hours.

Sternberg[3] states that 1 per cent. of nitrogen peroxide in air will sterilize vaccine in six hours, while $\frac{1}{4}$ per cent. was not disinfectant. He makes this power to be identical with those of sulphurous acid and chlorine. There is, therefore, no apparent benefit resulting from its use. Severe bronchitis and several deaths from poisoning have been recorded as resulting from breathing this gas (*Angus Smith*).

Nitrous Ether (ethyl nitrite), $C_2H_5NO_2$, was tried both

[1] *Comptes rendus*, March 6, 1871.
[2] *Journ. Med. Science*, Dublin, 1881, p. 508.
[3] *National Board of Health*, Washington, 1881.

as an antiseptic and disinfectant by Peyrusson and by Guillaumet in 1881. The former considered that it disengaged ozone.[1] Vallin's experiments prove it useless.[2] Miquel states that in fifteen to twenty days at 20° C. it was absolutely incapable of destroying the vitality of bacteria.[3]

Nitrobenzene will be alluded to among organic compounds, Chapter IX.

In conclusion, the opinion is irresistible that nitric disinfection is the worst of all methods, and under no circumstances should be allowed. Fortunately the patents are few.

Sulphur and its Compounds.

The abundance of this element in volcanic districts, and the characteristic odour of sulphurous acid and sulphuretted hydrogen, seem to account for the fact that sulphur and its compounds have had the earliest reputation as antiseptics and disinfectants.

In Fawkes' translation of Theocritus we read—

> "Next with pure sulphur purge the house and bring
> The purest water from the freshest spring,
> This mixed with salt and with green olive crown'd
> Will clease the late contaminated ground."

Sulphurous acid is still an *official* disinfectant; its ease of application and cheapness being its principal merits. The element itself, in the form of "flowers," is dusted on plants to kill aphides, and is extensively used for vines against *Oidium,* as well as for hops and seeds. Here it, undoubtedly, by slow oxidation, gives off sulphurous acid. (A wash used in America contains lime 30 lb., sulphur 20 lb., salt 15 lb., water 60 gallons). Mixed with soap it generates an alkaline sulphide, and this in turn, by the action of the carbonic acid of the atmosphere, liberates sulphuretted hydrogen. Given internally, as "flowers" or "milk" of sulphur, it also creates sulphuretted hydrogen in the body, evolved subsequently by the skin, and killing or enfeebling such parasites and micro-organisms as cause many of the skin diseases.

[1] *Comptes rendus*, 1881, p. 492.
[2] *Désinfectants*, p. 214.
[3] *Org. de l'Atmosph.*, p. 291.

So "brimstone and treacle," and the modern "sulphur lozenges," reach their reputation. In ointments also it is absorbed. The utility is undoubted, though the action is slow. To quicken it, it must be combined with oxygen or hydrogen, so as to be soluble in water, and diffusible in air.

Sulphuretted Hydrogen, H_2S.—This gas is slightly heavier than air, soluble in water (3 volumes dissolve in 1 of water at 15·5° C.), slightly acid, and blackens silver and some other metals. Its odour is well known, and it acts as a depressant poison, reducing the blood colouring matter of animals to methæmoglobin, which is incapable of carrying out respiration. It is, therefore, not suitable for an aërial disinfectant. Since it destroys most bacteria, especially that of tubercle, Dr. Bergeon[1] has employed it with marked success, by anal injections of the saturated aqueous solution, for pulmonary phthisis, etc. Niepce inhales the gas, but the former plan seems better, as not so toxic, since Claude Bernard has established the fact that some gases, which are poisonous when passed into the arterial system, become innocuous in the venous-per-intestinal absorption. Breathing continually small quantities of sulphuretted hydrogen is without doubt injurious to health, producing anæmia and low vitality.

The soluble sulphides of the alkalies and alkaline earths have similar properties, giving off the gas on exposure to air. Hence probably the use of sulphur springs for cutaneous affections.

In Choulet's patent 11,535 of 1902, calcium carbide is mixed with 10 per cent. or more of calcium sulphate or phosphate. The mixture is said to liberate a large amount of hydrogen sulphide or phosphide along with the acetylene when it is treated with water, and it is therefore claimed to be specially applicable to the destruction of insects and cryptogamic growths on vines and other plants.

Dr. Percy F. Frankland found that sulphuretted hydrogen was detrimental to the vitality of *Bacillus pyocyaneus*, Koch's bacillus, and *Spirillum Finkleri*, the ones specially selected as typical; also to the majority of microbes, a few, however, thriving on it.[2] It must be remembered that

[1] *Brit. Med. Journ.*, Dec. 18, 1886.
[2] *Proc. Roy. Soc.*, vol. xiv., p. 292.

sulphuretted hydrogen is itself one of the products of putrefaction, one class of organisms not only reducing the sulphates to sulphides, but some of them also converting the latter into solid sulphur within their protoplasm. To such, which are not the more dangerous ones, sulphuretted hydrogen would do no harm.

This gas is a reducing agent by means of its hydrogen, sulphur being liberated. It is destroyed by all oxidizing agents, eventually producing sulphuric acid. The action of chlorine, bromine, and iodine upon it has already been mentioned (p. 79). Lime and alkalies, and salts of the heavy metals, except those of aluminium, absorb it, forming sulphides. Ordinary acids, except nitric, do not remove it beyond the extent of its solubility in water. Sulphurous acid decomposes it:

$$2H_2S + SO_2 = 2H_2O + 3S.$$

In sewer gas ammonium sulphide, as fœtid and poisonous as sulphuretted hydrogen itself, often exists and seems to be one of the narcotic agents causing suffocation in sewers. If paper moistened with lead acetate be discoloured by any emanations, sewer gas is indicated, unless it be derived from a chemical or gas works. The absence of sulphuretted hydrogen or of smell is, however, no proof of efficient disinfection. Many so-called disinfectants, moreover, merely mask one smell by creating another. Even the presence of excess, as shown by the odour of the disinfectant, does not prove efficiency; there must beyond this be a sufficient percentage present, ascertainable only by experiment and calculation.

Sulphur Dioxide or sulphurous anhydride, SO_2, is a colourless gas of specific gravity 32 (air = 14·45), with the well-known odour of burning sulphur. One litre weighs nearly 3 grammes. It is obtained by burning sulphur or a sulphide in air—

$$S + O_2 = SO_2.$$

One kilogramme of sulphur gives 700 litres of the gas.

It is irrespirable, producing violent coughing and suffocation. About 5 per cent. in air has produced fatal results, causing acute catarrh, acid eructations, anorexia, irregularity of the bowels, and permanently impaired digestion

(*Hirt, Eulenberg*, etc.), but ½ per cent. can be endured for a length of time. A wet towel moistened with washing soda enables a larger amount to be faced.

One litre of water at ordinary temperature dissolves 50 litres, or 145 grammes, producing an acid liquid containing the unstable H_2SO_3—

$$SO_2 + H_2O = H_2SO_3.$$

This liquid smells strongly of the gas, as, gradually at ordinary temperatures and rapidly on heating, it decomposes again into sulphur dioxide and water. Hence it rapidly loses its strength unless well stoppered. (It only slowly attacks corks, so that it can be kept in a corked bottle). In the anhydrous state it is not disinfectant; on adding water it becomes active: hence the term "sulphurous acid" will be used throughout for this agent, as more familiar and accurate. It acts in four ways:—

1. As an acid it absorbs ammonia, compound ammonias, and organic bases like "ptomaines" and the products of growth of pathogenic organisms. The salts so formed (sulphites) are much less injurious. It has this property in common with other acids.

2. It decomposes sulphides and sulphuretted hydrogen, as above shown.

3. It reduces organic matters, or combines with them, to form compounds which are in most cases inert. This explains its bleaching action on vegetable colours, as the compounds formed are nearly colourless. But the action is evanescent, as on exposure to air it is oxidized to sulphuric acid, and the colour often re-appears.

4. As a poison it kills living organisms.

The gas can be easily condensed to a colourless liquid by pressure, and preserved in strong metal vessels. About 3 atmospheres (45 lbs. on the square inch) is sufficient. Messrs. Boake & Co.[1] have introduced commercially this liquefied gas, and as it is attainable in any quantity at a cheap rate, it is much more convenient to employ than sulphur. The vessels are opened by a lever attached to a screw. The gas will flow steadily for forty hours, a single

[1] Patent No. 12,238, 1885.

syphon evolving 500 litres of gas, equal to the amount obtained from about 1½ lbs. of sulphur. This firm also make hermetically sealed tins which are sufficient for the disinfection of a small room. The gas is obtained by cutting with a knife the soft metal pipe attached to the tin. Each tin contains about 20 ozs. of liquefied gas, and is stated to be sufficient for the disinfection of a room 12 ft. cube (1,728 cubic feet).

Sponges are frequently disinfected and bleached by first immersing them in a bath of hyposulphite of soda (½ lb. to 1 gallon water), and then adding ½ lb. of oxalic acid in crystals; sulphurous acid is liberated and sulphur deposited in the pores of the sponges. After washing with boiled water, they can be kept in a weak carbolic acid solution.

The Governments of England, United States, Belgium, France, Austria, Sweden, and some others prescribe fumigation by burning sulphur for infected rooms. Hence, as Arnould says, it is the "official disinfectant *par excellence*." Germany, amongst European nations, however, does not recommend it officially, and in Berlin sulphur disinfection is not much employed. The British Local Government Board prescribed that for a moderate sized room 1½ lbs. of sulphur should be burnt over a small fire and the room kept sealed for 6 hours or more. (As 1 lb. of S yields 11·7 cub. ft. of SO_2, the above quantity would give 1·75 per cent. in the air if the room were 1,000 cub. ft.) The wall paper is then to be stripped off and burnt, and the ceiling and floors thoroughly washed, etc. The Society of Medical Officers of Health suggested also that bedding and clothes should be spread out on lines, that the sulphur should be burnt over a pail of water to supply moisture (but on this point see p. 134), and that the time should be twenty-four hours. Other official recommendations were: Belgium, 20 to 30 grammes per cub. metre, = 2 to 3 per cent. SO_2 in the air; Paris, 20 grammes per cub. metre for 48 hours; American Committee on Disinfection, 1885, *at least* 4 per cent. SO_2 for twelve hours in presence of moisture, equal to 1½ to 2 kilos. S for every 28 cub. metres (about 1,000 cub. ft.) (See also p. 76). For ships arriving in the Mississippi from infected ports, the cargo is sprayed with corrosive sublimate solution, but sulphur fumigation is used for the hold. A battery of 18

furnaces contained in a specially constructed tug is used for heating the sulphur, and the gas mixed with air is forced into the hold at the rate of 180,000 cub. ft. per hour by means of a fan. 100 to 1,700 lbs. sulphur is used for each vessel, according to size.

The sulphur flame is very liable to extinction, and various devices have been introduced to remedy this defect. Corfield and Louis Parkes burn it in an iron vessel with a little spirit. Nicholls and Billyen, and also Vallin use 8 parts of flower of sulphur, 2 or 3 of nitre, and 2 or 3 of bran or liquorice powder. This would give a deflagration, would retain much of the sulphur in the residue as sulphate, and would result in rather too rapid an evolution, so that the inevitable leakage would be greater. Another plan is to place it on an iron tray and throw a shovelful of red-hot coals on it. When this plan is adopted, there is usually a residue of unburnt sulphur left. A chafing-dish of coals, *properly protected,* with an iron tray over it, and lumps of sulphur distributed gives better results. Even with these devices, it is almost impossible to keep up a combustion sufficiently long, and some of the sulphur is wasted by being sublimed. Mendeljeff also points out[1] that the sulphurous fumes, being given off hot, ascend to the ceiling, where they may be absorbed by the plaster, while some time is required for the gas to reach the lower portion of the room where it is most required. Hence the liquefied gas, excluding, as it does, the risk of fire, is much to be preferred.

T. A. Clayton has designed a large apparatus for generating SO_2 by combustion, and for using the gas in the hot state if required.[2] Moore & Martin's U.S. patent, 700,537, of 1902, is another large generator.

Kingzett's sulphur candles are made in the form of a night-light, and are placed in a water-jacket as a precaution against fire. They are made of sulphur with a "powerful oxidizing agent," and a wick, and are arranged to burn two hours. They are very convenient if a sufficient number are used, and the cost is moderate.

Seabury's sulphur candles[3] also burn two hours, and

[1] *Principles of Chemistry*, p. 40.
[2] Patent 4892 of 1902. *Pub. Health Engineer*, April 19th, 1902.
[3] Patent No. 6,407, 1893.

differ from the above in having a large compound wick. Morse and Bourne's patent,[1] Wades,[2] and Shaw's U.S. patent, 698,748, of 1902, affect various details in the candles.

Neutral sulphites, such as sodium sulphite, Na_2SO_3, are not decomposed like hypochlorites by the carbonic acid of the air, hence they neither smell of nor give off sulphur dioxide. Both the acid and its salts absorb oxygen from the air, changing to sulphates, and therefore they act as reducing agents. The acid or bisulphites of sodium, calcium, and magnesium are much used for preserving provisions; they slowly evolve sulphurous acid gas. The sulphites, as distinguished from the free acid, are poor disinfectants, but a large number of patents have been taken out for their use either alone or in mixtures. Most of these patents are of doubtful utility.

A bisulphate mixed with a bisulphite would be a convenient form, which would evolve sulphurous acid on being moistened, thus—

$$NaHSO_4 + NaHSO_3 = Na_2SO_4 + H_2O + SO_2.$$

R. V. Tuson[3] suggested the use of various metallic sulphites, and[4] proposed to employ a saturated solution of sulphurous acid in liquid phenol.

M'Dougal and Meldrum[5] state that "the prejudicial and offensive products of the decomposition of sewage matter are mainly compounds of sulphur and phosphorus with hydrogen or alkalies. Sulphurous acid decomposes these, forming thiosulphates, hypophosphites, etc. This is the base of the process. The gas is generated by burning sulphur, pyrites or the spent oxide of gas works, and passed in until the liquid is acid."

Thiocamf (Prof. E. Reynolds) is a liquid formed by leading sulphurous acid into a bottle containing camphor. The resulting product contains 30 to 35 per cent. of sulphur dioxide. Various other disinfectants (not oxidizers) can be mixed with it. On exposure to air it gives off its sulphurous acid and leaves a white antiseptic residue of, presumably,

[1] No. 18,434, 1891.
[2] No. 18,511 of 1898.
[3] Patent No. 8,645, 1879.
[4] Patent No. 1,081, 1879.
[5] Patent No. 2,846, 1891.

camphor. A 6-ounce bottle evolves about 20 litres of gas. It was recommended by the Disinfecting Committee of the House of Commons.

There has been a great conflict of opinion on the value of sulphurous acid disinfection. Vallin[1] pronounced it perfect, Arnould[2] says that "sulphurous acid, even in the almost inapplicable dose of 10 per cent., is an uncertain means of destroying spores, even moisture does not ensure success." Dr. Cassedebat, after a research at the Marseilles School of Medicine,[3] remarks "even in the highest dose, it is too inconstant to be recognised in the disinfection of virus." Savarelli[4] condemns it. Miquel could not kill germs in twenty days.[5] Sternberg's experiments[6] were unfavourable—"it requires special conditions rather than abundance." Dr. A. J. Martin[7] says "its efficacy is contestible, without counting its public nuisance."

Dujardin-Beaumetz,[8] who studied the behaviour of this gas with Pasteur and Roux, found that 20 grammes of sulphur, as used in the official French fumigation, did not kill *Bacillus anthracis,* though it sterilized tubes of vaccine.[9] Since Wolffhügel's experiments[10] in 1881, sulphurous acid has quite lost its reputation in Germany. Koch[11] obtained similar results; he spread the spores about in a room where sulphur was burnt, or laid them on boards, which were then washed or sprayed with a solution of sulphurous acid and tested by transference to culture solutions or by inoculation.[12]

Dubief and Bruhl[13] state that "sulphurous acid has the most destructive effect on aërial microbes, especially moist, acting mainly on the spores of bacteria, and when pure and acting for a long period, it may prove fatal to dry germs."

[1] *Traité des Désinfectants.*
[2] *Hygiène*, 1889, p. 501.
[3] *Revue de Hygiène*, 1891.
[4] *Giorn. Soc. Ital. d'Hyg.*, 1890.
[5] *Les Org. vivants de l'Atmosph.*, 1883, p. 289, *et seq.*
[6] *Med News of Philadelphia*, March 28, 1885.
[7] *Soc. de Med. Publique*, 1892.
[8] *Bull. de l'Acad de Med.*, Sept. 9, 1884.
[9] See Rochard's *Encyclopædie d'Hygiène*, vol. v., 1893.
[10] *Mittheil. a d. Kais. Gesundh.*, vol. i., p. 188.
[11] *Ibid.*, p. 234.
[12] Wolffhügel and Proskauer, *Chem Centralblatt*, vol xiii., p. 334.
[13] *Comptes rendus*, 1889.

M. d'Abaddée states that of the Sicilian labourers engaged in sulphur works only 8 or 9 per cent. suffer from intermittent fever as against 90 per cent. of those not so occupied. The sulphur works in the marshy plain of Catania protect the people in the vicinity from an evil that causes other villages to be deserted.[1] This tends to prove that sulphurous acid is strongly antagonistic to malaria.

Dr. P. Frankland[2] found that it killed several pathogenic organisms. Baumann destroyed *B. tuberculosis* with it, and has cured several cases of early phthisis by burning sulphur.

Drs. Marsh and Watkins-Pitchford from trials in an experimental room, of 1,152 cub. ft., at the Government Research Laboratory, Bombay, in June, 1898, reported that the contents of a cylinder of compressed SO_2 destroyed the plague bacillus in 20 hours, even when protected by one to three thickness of cotton or linen, or by thin coverings of earth, wool, leaves or paper.

Klein has furnished a key to these discrepancies by showing that although "most pathogenic microbes do not thrive in an acid medium, some putrefactive and zymogenic organisms can thrive well in acid—*e.g.*, *Bacillus subtilis*, *Micrococcus ureæ* in acid urine, etc."[3] Therefore, sulphur disinfection, though generally successful, may sometimes fail. Wynter Blyth is also of the same opinion.

M. Thoinot sums up thus in his *Report to the Committee of Public Hygiene of the Seine*, 1891—"The disinfection by sulphurous acid is only a practice of waiting, but it is a good practice, and ought not to be despised."[4]

The author has experimented on the disinfection of rooms using the liquefied gas, and the results obtained may be briefly summarised as follows: Silk threads and paper slips infected with *B. coli communis* and *Staph. p. aureus* were sterilized after 24 hours' exposure in a sealed room, of 1,500 cubic feet, into which 20 ozs. of SO_2 were passed. *Subtilis*

[1] *Journ. Soc. Chem. Ind.*, vol. i., p. 515.

[2] *Proc. Roy. Soc.*, vol. xlv., p. 292.

[3] *Micro-Organisms and Diseases*, 1886, p. 258.

[4] See also Klein, Lawes and Lingard in *Report of M. Off. of Local Gov. Board*, 1884, on "Chlorine and sulphurous acid on Swine fever virus"; and Crookshank's *Bacteriology*, 1887, p. 150.

spores were not killed. Using 10 ozs. of the gas, the silk threads infected with *B. coli communis* and *Staph. p. aureus* were again sterilized but the paper slips were not. An important point was brought out by a repetition of this experiment, exposing shallow pans of water in the room in order to moisten the air during the disinfection: the SO_2 content of the air of the room was actually lowered after the 24 hours, through absorption by the water, from 0·5 per cent., present in the previous experiment, to 0·2 per cent., and the coli and staphylococcus were not destroyed either in the paper or silk threads. Disinfection with liquid SO_2 can be used for all purposes for which burning sulphur is efficacious, and possesses the advantages over the latter of freedom from risk of fire and convenience in application. The quantity of aqueous vapour normally present in the air in England is sufficient to ensure the activity of the gas, and the above experiment shows that the exposure of large wet surfaces is to be avoided.

It was objected to the halogens that they were apt to corrode the fabrics submitted to them. The same thing is liable to happen with sulphurous acid, as its oxidation in air leaves behind sulphuric acid, which is not volatile.

Sulphurous acid and the bisulphites are widely used for preserving food. They act (1) by absorbing oxygen, (2) by suspending the growth of moulds and ferments, like those of the vinous, acetous, lactic, and butyric fermentations. In canned goods they are objectionable, as they dissolve tin and lead from the metallic envelope. Nicolaïdi[1] preserves milk intended for butter and cheese making, by adding with a special apparatus a definite proportion of sulphurous acid: the preservative passes into the whey. Dr. Pfeiffer, of Munich, asserts that large quantities of sulphurous acid and bisulphites in beer, etc., are undoubtedly injurious to health. The maximum allowed for wine and beer in Austria is 8 milligrammes per litre, on the basis of the opinion of the Medical Faculty, March 19, 1887. But at least 40 milligrammes per litre might be allowed without injury.[2] Nessler says that 2·7 to 5·4 milligrammes per litre is sufficient to

[1] French patent 322,081 of 1902.

[2] Lehmann's *Hygiene*, translated by Crookes, 1893.

prevent secondary changes in wine, whilst 22 milligrammes suppresses fermentation for fully twenty-eight days.

Beythien and Bohrisch[1] found unusually large quantities of sulphites in a number of dried fruits, principally American.

Calcium and magnesium bisulphites, like sulphurous acid, in more than a minute trace, spoil the flavour of most foods, giving a flatness and metallic taste which is distinctly perceptible. These salts are extensively used in beer (in finings), in wines and fruit syrups to absorb oxygen, and to hinder secondary fermentations. They are the least noxious of preparations of this kind. L. Pfeiffer, in a paper on the poisonous action of sulphurous acid and its salts,[2] states that sulphites are sometimes added to wine in such quantities as to produce injurious results. Out of eighty specimens of wines examined by Kammerer, sixteen contained sulphites in quantities ranging from ·017 to ·093 gramme per litre. List detected sulphites in a large number of French wines, the amount varying from ·009 to ·135 gramme per litre. Their presence in wines is likely to cause irritation, if the quantity of acid exceeds 0.08 gramme per litre.

Kionka[3] tested the effect of sodium sulphite, in the proportion commonly used as a preservative, upon dogs. He found that after continued consumption of such food, serious symptoms of blood poisoning, which are described, supervened. Hitherto, observations on the human body have yielded few positive results, but evidence generally is against the use of sulphites.

Boake and Roberts prepare a "formaldehyde potassium metabisulphite,"[4] $CH_2O,K_2S_3O_5$, as an antiseptic: on adding acid it gives formaldehyde and SO_2. Calcium sulphite is recommended by M. Gelle[5] as an internal antiseptic against influenza, in doses of 0·06 grm. daily (in pills) for 3 consecutive days.

Johnson and Saladin[6] propose an apparatus for cleansing grain, freeing it from dust, germs, etc., by blowing and

[1] *Zeits. Unters. Nahr. u. Genussmittel*, 1902, v., 501.
[2] *Med. Chronicle*, Oct. 1890.
[3] *Deut. mediz. Wochenschr.*, 1902, xxviii., 89.
[4] Patent 15,819 (of 1898).
[5] *Amer. Druggist and Pharm. Record*, 1895.
[6] Patent No. 689, 1893.

washing, and sterilizing with sulphurous acid, vapour of bisulphide of carbon, or other gas or vapour, by a tower arrangement down which the grain falls, and is distributed and mixed in its course by baffling or deflecting pins. Thiosulphates (the "hyposulphites" of commerce) are antiseptic, but not strongly.

Sulphuric Acid, H_2SO_4, like acids generally, is antiseptic; it is only partially a disinfectant. Koch first announced that the cholera bacillus was affected by acids. Kitasato subsequently showed that both this acid and hydrochloric destroyed cholera germs in a few hours.

A. Stutzer[1] states that a solution of 0·05 per cent. of sulphuric acid is fatal to cholera bacilli in fifteen minutes (see Klein's remark, *ante*, p. 133). He tried 0·02 per cent., which took twenty-four hours; 0·03 per cent. in five hours did not kill all the organisms. He also examined whether iron pipes could be disinfected by sulphuric acid without corrosion, and found that it cleaned out rust and sediment and did not sensibly attack the metal. He estimates that 100 kilos. of 60° B. sulphuric acid (1 lb. of acid to 40 gallons of water) would disinfect 40,000 litres of water at an expense for acid of about 0·9d. per 100 gallons of water treated. Dr. Ivanoff[2] has also demonstrated that 0·04 per cent. of this acid destroys cholera bacilli in Berlin sewage, and 0·08 per cent. in that from Potsdam.

According to Miquel, 2 or 3 grammes of sulphuric acid produces an equal effect to 7 milligrammes of mercuric chloride. Endemann[3] found it very difficult to develop bacteria in fluids containing acid phosphates. Whitthread's patent, 1872, for precipitating sewage by acid phosphate of lime and then milk of lime, was tried at Luton in 1874, and very favourably reported on by Corfield. He used a solution of 1 in 1,000. The use of acid phosphates was proposed previously by David Forbes, and several patents claim them as disinfectants.[4] Endemann has also shown that many acids are powerfully disinfectant, destroying the life of bacteria completely, even if present in small quantities (but

[1] *Zeitsch. für Hyg.*, 1893, p. 116.
[2] *Ibid.*, 1893, p. 86.
[3] *Chem. News*, vol. xli., p. 152.
[4] Corfield and Parkes, on *Treatment and Utilization of Sewage*, 1887, p. 306.

not of spores?). One part of hydrochloric acid in 64 parts of Cohn's fluid well stocked with bacteria, destroyed these completely. In the Liernur process, and in Beck and Henkel's patent 21,856, 1901, sewage is sterilized by sulphuric acid.

The toxine *Cadaverine*, $C_5H_{14}N_2$ (*Brieger*), occurs in the products of cultivation of the cholera bacillus. Kobert[1] says that it is less dangerous when converted into a neutral salt. To this he attributes partly the benefit derived in cholera from acid drinks (see later, Chap. XIII.), and from washing the intestines with acid liquids, of which weak sulphuric is the best, especially as it has been shown that the cholera bacillus itself is affected by traces of acid.

Rohe[2] is of the opinion that whilst sulphuric acid, 1 in 800, is antiseptic in some cases, it cannot be depended on as a general antiseptic. The subject is further dealt with in Chapters XII. to XIV.

The SULPHATES are not perceptibly antiseptic. Miquel concludes that sodium and potassium sulphates, even dissolved to saturation in beef tea, are incapable of preventing the germination of bacteria. Sulphates of lime and magnesia actually encourage the growth of many organisms, being reduced to sulphides. Those of iron, mercury, and some other metals depend for their power on the base present, and not on the acid. Acid sulphates will be noticed later.

PERSULPHATES. J. Wacker[3] stated that ammonium persulphate in 1 to 2 per cent. solution has a very powerful disinfectant action, killing cholera and other germs in a few minutes, preserving fresh fish and flesh, and deodorizing fæces. The salt has scarcely any action on animals. Friedländer[4] reported that 1 per cent. sodium persulphate prevented putrefaction in broth and wine, that 0·2 per cent. was fatal to Sp. choleræ, and that 0.5 per cent. destroyed most other bacteria. It had proved a useful substitute for potassium chlorate in affections of the throat and mouth, and in 3 to 5 per cent. solution as a successful antiseptic for wounds, but it attacks and oxidizes metallic instruments.

[1] *Pharm. Centralhalle*, 1891, p. 162.
[2] *Hygiene*, 1890, p. 357.
[3] *Chem. Cent.*, 1894, xxi., 873.
[4] *Pharm. Centralhalle*, 1899, xl., 102.

The sodium salt is preferable to that of potassium, since it is free from irritant action.

Bisulphide of Carbon, CS_2, is a colourless liquid, very volatile (boiling point 46° C.), and exceedingly inflammable; the vapour has caused dangerous explosions. It is heavier than water (sp. gr. 1·292), and insoluble in it. It has ordinarily a most offensive odour and is extremely poisonous, its vapours forming in the blood methæmoglobin, with destruction of the corpuscles.[1] In Patent No. 3,208, 1878, M. Simon exposes meat to the vapour of this compound for preservation.

Dujardin-Beaumetz used carbon bisulphide internally for typhoid and diarrhœa, and found that "all offensive odours were removed from the breath, and the stools were disinfected."[2]

By burning, it generates large quantities of sulphurous acid mixed with carbon dioxide. The yield cannot well be increased by dissolving sulphur in it, as the latter mostly remains unburnt in the dish.

Messrs. Price & Co. have devised a lamp for burning this liquid so as to generate these gases,[3] but it must be used with caution on account of its volatility and inflammability. *La Nature*, xxiv., 117, states that it can be burnt with great regularity and without any danger in a lamp invented by Ckeandi Bey, and figured in Thorpe's Dict. of Chemistry, vol. I., p. 443. About 5½ lbs. are said to be required for a room of 3,500 cub. ft.

Carbon bisulphide is decidedly antiseptic, but its characteristics prevent its use. In combination with sulphides of alkalies it yields the sulphocarbonates, such as the potassium salt K_2CS_3, which crystallizes in yellow needles, soluble in water and unstable. With an alcoholic solution of potash it forms an ethyl-sulphocarbonate or xanthate, $CS(OC_2H_5)SH$.

According to P. Zoller,[4] small quantities of xanthates mixed with the soil prevent the inroads of fungi. Zoller and Grete[5] recommend potassium xanthate as a remedy against *Phylloxera*.

[1] See Westberg, *Zeitsch. für Anal. Chem.*, vol. xxxi. [4], p. 484.
[2] *Comptes rendus*, vol. xcix., p. 509.
[3] Parkes, *Hygiene*, p. 517.
[4] *Dingl. pol. J.*, vol. ccxxi., p. 191; vol. ccxxii., p. 190.
[5] *Berichte.*, vol. viii., pp. 802, 955.

Aqueous solutions containing 1 or 2 grammes of carbon bisulphide per litre have also been found very satisfactory against *Phylloxera*.[1]

Boric Acid and Borates.

Boric or Boracic Acid, H_3BO_3 (or $HBO_2 . H_2O$) occurs in inodorous, pearly crystalline scales. The solubility in water and in alcohol of 90 per cent. is about the same, 1 in 30. It dissolves in three parts of boiling water, and in four of glycerine.[2] It has been proposed, in an Italian patent, to import it from Tuscany in the form of the native solution, but the cost of transport would thereby be increased.

It is a weak acid, almost tasteless in dilute solution, and has no corrosive action either on tissues or metals; this and its absence of odour, with a certain amount of preservative power, and little effect on animals, have led to a large number of patents for the use of boric acid and borates for preventing the putrefaction of animal and vegetable substances. It is in no sense a disinfectant, and its antiseptic powers are low, although for many years it has held a place as a preservative for meat and vegetables. The original discoverer, Gahn, sold in Europe two mixtures—(1) boric acid with 1 part alum, called "aseptine"; and (2) boric acid with 2 parts alum, called "double aseptine." It seems probable that he recognised in the alum a greater activity than in the boric acid. Provisions in part preserved by boric acid are generally within one or two months covered with a black crust, but the presence of alum prevents this action taking place. Lehmann found that fresh beef with 1 per cent. of boric acid and 50 per cent. salt pickle kept for several months at 80° F. Endemann stated[3] that boric acid acted as a preservative to fresh meat only, and that previously salted meat could not be preserved by it. Lehmann infers in these cases it is not the boric acid that acts as a preservative, but the substances produced by it, *i.e.*, the acid phosphates (see under sulphuric acid, p. 136). He states that "other mineral acids give exactly the same results without boric, especially phosphoric and hydrochloric."[4]

[1] *Comptes rendus*, 1891, pp. 1113, 1283, and 1330.
[2] *Brit. Phar.*, 1898.
[3] *Chem. News*, April 2, 1880.
[4] Lehmann, *Practical Hygiene*, 1893, vol. ii., p. 247.

Miquel classes it as "moderately antiseptic." It required 7·5 grammes to "neutralize" a litre of beef tea.

According to Lazarus,[1] milk can only be preserved by boric acid, if the quantity added exceeds that which can be used without altering the taste, as the microbicidal action of boric acid is very feeble. He is of the opinion that from 1 to 2 grammes per litre is without action (compare Miquel); yet Stokes[2] states that 1 to 1,000, or roughly 7 grains per pint of boric acid will keep milk "sweet" for forty hours. The difference is a question of time.

Mattern finds 1 per 1000 retards the coagulation of milk from twenty-four to thirty-six hours.

This acid has no action on vinous fermentation; it retards the formation of acetic acid from alcohol by *Mycoderma aceti* only when acetic acid is not already present.[3] Lehmann sums up thus—"preservation by boric acid cannot be considered as involving a new principle; it is merely a variation of, but by no means an improvement on, vinegar pickling. The insipidity prevents its easy detection, and brings customers to the belief that the meat is fresh. This peculiarity is the only one recommending the use of boric acid." Dr. C. T. Williams, of Brompton Hospital, proved that the acid exercised no destructive influence on the bacilli of phthisis; in fact they increased abundantly in boric solution. A warm saturated solution was recommended by Pasteur as an antiseptic in cases of puerperal fever, but has been superseded by mercuric chloride in the lying-in hospitals of Paris. Boric ointment when used for burns has produced poisonous symptoms.[4] The application of the acid to wounds and ulcers has decreased,[5] and in the French Army Medical Service, four times as much sublimate wool is used as that impregnated with carbolic or boric acid. The latter wool contains from 14 to 36 per cent. of boric acid, which is in great part crystallized, and therefore irritating to the skin, but the crystallization may be prevented by keeping the wool moist by glycerine.[6] There is

[1] *Zeits. f. Hygiene*, vol. viii.
[2] *Analyst*, 1891, p. 123.
[3] Herzen, *Biedermann's Centralblatt*, 1880, p. 487.
[4] Dr. A. Hall, *Med. Reprints*, June 15, 1896.
[5] *Lancet*, vol. i, 1890, p. 1266.
[6] *Chemist and Druggist*, Feb. 18th, 1893.

no doubt that boric acid does preserve food when used in sufficient quantity. The earlier investigators employed such strengths as 1 in 12 (*Jalan de la Croix*); ½ to 4 per cent. (*Neumann*); whilst Vallin, who used 2 to 4 per cent. of the acid, states that this strength kills germs when borax only stupefies them.[1]

Borates.—Those occurring naturally are Tincal or native Borax, Boracite or Magnesium borate, and Borocalcite or Calcium borate, and others of less importance. Those which are soluble are somewhat antiseptic; they are decomposed by strong acids. The acid magnesium biborate is one of the most soluble, and has been recommended as a preservative.[2]

Borax, or Sodium diborate, $Na_2B_4O_7,10H_2O$, occurs in large transparent crystals, inodorous, having an alkaline taste and reaction, and soluble in 12 parts of water. M. Dumas, in August, 1872, introduced boric acid and borax to the French Institute as preservatives for food. Borax has been used to neutralize the acid developed in milk by keeping. E. le Cyon[3] thinks that meat preserved by borax is not diminished in nourishment, and is more readily assimilated. Subsequent investigators have, however, arrived at an opposite conclusion.

Ammonium Borate is more soluble; a strong solution has been injected into bodies for dissection.

Among the earlier patents are—No. 2,375, 1877, Taylor, calcium borate; No. 3,001, 1880, Artimini, "boric tartrate" as an antiseptic; No. 4,910, ditto, ditto, boric acid and borax; No. 1,127, 1882, J. Imray, preserving meat with boric and malic acids; provisional protection; 1882, Haddan, borax, glucose, and boric acid evaporated till solid, for provisions; No. 5,153, 1882, Pielsticker, boric acid melted with sodium phosphate and formate, "very soluble and almost tasteless, for provisions"; No. 6,134, 1882, J. Townsend, boric acid, etc.; No. 274, 1883, Wilkins, ditto (these two are mainly mechanical); No. 1,429, 1883, Conron, boric acid, borax and potassium nitrate, "half a pint of concentrated solution to a barrel of 36 gallons," for various infusions; No. 5,326,

[1] *Désinfectants*, p. 149.
[2] *Brit. Med. Journ.*, 1888, p. 1184.
[3] *Bied. Centr. Agr. Chem.*, 1879, p. 869.

1883, Lake, glycerine and boric acid, not heated; compare Barff's patent:—

"Boroglyceride," No. 1,332, 1881, F. S. Barff, deserves further mention. "Heat glycerine to near its boiling point, and add boric acid as long as dissolved. Keep at 200° C. as long as water comes off. Animal or vegetable matter is preserved by immersion in a solution of the compound in water, alcohol, or other solvent." Boroglyceride claims to be *glyceryl triborate*—

$$C_3H_5(OH)_3 + 3HBO_2 = C_3H_5(BO_2)_3 + 3H_2O.$$

How far, like other esters, dilution breaks it up again into glycerine and the acid, is not apparent. The solution has a different taste from the materials, but the general properties are intermediate in their character. It has hardly answered expectation. See later under *Glycerine* for the therapeutic effect of that body. Calcium and sodium boroglycerates, obtained by heating calcium borate or borax with glycerine till the whole forms an oily liquid which solidifies on cooling, are recommended by Le Bon[1] for preserving food and for surgery.

It will be noticed that most of the above devices are intended to increase the sparing solubility of boric acid. It is one of its characteristics that, though having so feeble an affinity for bases, it seems always ready to form more or less stable combinations with other acids and with neutral bodies.

Potassic Borotartrate or "Soluble Tartar," $K(BO)C_4H_4O_6$, obtained by heating together 1 part of boric acid, 2 of cream of tartar, $KHC_4H_4O_6$, and 24 of water, evaporating to dryness, and treating with alcohol to remove excess of acid, is a white non-crystalline powder, insoluble in alcohol but very soluble in water. It has been employed as a purgative, and also as an antiseptic, and is the "boric tartrate" of Artimini's patent mentioned above.

Benzoboric acid, with oils of thyme, *Eucalyptus, Baptisia, Gaultheria,* and *Mentha arvensis,* containing 1 part of the acid in 30 of the oils, is called "Listerine," and is used in surgery. According to a report of the Pasteur Institute, Paris, the toxicity is $\frac{1}{146}$ of that of carbolic acid, and the mixture of oils has more power than any one of them singly.[2]

[1] *Comptes rendus,* vol. xcv., p. 145.
[2] *Chemist and Druggist,* June 30th, 1903.

There is also a benzo-boric mouth-wash. Salicylic acid is soluble in less than 600 parts of water; stronger solutions may be made by using boric acid in the proportion of 12 parts boric acid to 1,000 of water, when a 0·2 per cent. solution of salicylic acid can be obtained.[1] Strock's "Antiseptic paper" is made with two solutions—A, alcohol 500, boric acid 5, salicylic 7; B, water 1,588, sodium thiosulphate 60.[2] Radlauer's "Antisepsin" is a mixture of zinc sulphate 85, zinc iodide 25, thymol 2·5, with 10 parts of boric acid.

L. Hausler[3] has recently made boroglyceride into a jelly by dissolving it in hot water with half or an equal weight of gelatine; he dips the provisions while the jelly is still liquid, and so gives them a protective coating. Before use the articles are washed in luke-warm water.

Boric acid is also used for preserving butter and cream, for curing hams, sprinkling over fish, etc. "Sodium chloro-borosum" is borax and common salt. "Barmenite," according to C. Schwartz, contains 80 per cent. borax, 15 boric acid, 3 salt, and 2 sodium chlorate, with traces of alumina. "Glacialin" is a fused mixture of borax and boric acid.[4] These preparations have been extensively used on the Continent for preserving meat, and the latter in this country for milk. How much boric acid enters into meat which is sprinkled with or soaked in it, is not accurately known, but according to Roosen, who has patented the use of boric solution under pressure, 500 grammes of meat take up only $\frac{1}{4}$ gramme of the acid. Covering meat with 1 per cent. boric solution keeps it from putrefaction from four to seven days.

Hehner states,[5] on the authority of Polenski, that in Germany boric acid preservatives have been advertised under the following names:—Berlinite, Chinese preservative powder, Brockman's salt, Australian salt, Magdeburg preservative salt, and Heydrich's salt. The subject is further discussed in Chapter XIV.

Kayser[6] says that traces of boric acid are very widely

[1] *Revue de Chimie Industrielle*, April 15, 1893.
[2] *Ibid.*, Feb. 15, 1893.
[3] Patent No. 9,145, 1893.
[4] *Journ. Soc. Chem. Ind.*, 1890, p. 993.
[5] *Analyst*, 1890, p. 295.
[6] *Chem. Zeitung*, 1890.

distributed in nature. Carrots, beet sugar, Californian wines, etc., contain it, and it is often introduced into the glaze of enamelled vessels. Lippmann has detected it in lemons and oranges.[1] But these would only be minute traces, whereas as a preservative it would be present in comparatively large quantities.

Influence of Gases on Bacteria.

As to conditions of growth bacteria include:—I., the *aerobic*, which live and work in presence of oxygen, and cease to multiply when it is exhausted; their gaseous products are chiefly carbonic acid and ammonia. The larger putrefaction species were formerly massed together as *Bacterium termo;* they were dealt with by exclusion of air, as in preserving in tins, or by reducing agents such as sulphites, before sterilization was adopted. II., the *anaerobic*, which exist in absence of oxygen, and in many cases are killed by its presence: many of the pathogenic organisms belong to this latter class. Among the products are marsh gas, sulphuretted hydrogen, phosphoretted hydrogen, carbon monoxide, nitrogen, besides ptomaines. Oxidizing agents like chlorine, hydrogen peroxide, and permanganate, are their most effective destroyers. These bacteria take up the process where the aerobic have ceased, hence the necessity of sterilizing before excluding the air.

Dr. Thomas Beddoes established at Clifton, near Bristol, in 1793, a pneumatic institute for the treatment of chronic diseases, such as consumption, asthma, and cancer, by the inhalation of gases. James Watt constructed the apparatus, at a cost of £2,500, the money being raised by Thomas Wedgwood and other sympathizers. The institute was opened in 1798, and patients were put into rooms containing large proportions of oxygen, hydrogen, nitrogen, or carbonic acid gas, as might be indicated by the disease. Another apparatus used was a dusting-box, in which mechanical means were employed to make a dusty atmosphere with charcoal or powdered cinchona. The institute failed in its object—perhaps because the cases treated were

[1] *Chem. Zeit.*, 1902, xxvi., 465. Rost, E., *Bekanntmachung des Reichskanglers*; Springer, Berlin, 1903.

chronic, as the benefits of oxygen-inhalation are now sufficiently appreciated.

On the principle that all living beings are first debilitated, and finally killed by their own excretory products, any of the above gases generated by bacteria should be to a certain extent poisonous to the micro-organisms which produce them. But they may be far more fatal to higher animals, the effects being not only on the blood and the lungs, but also on the central nervous system; the more highly developed the organism, the greater is the sensibility.[1]

Oxygen under pressure, either alone or mixed with various non-disinfectant gases, has been the subject of numerous patents for preserving food and even for disinfection, but as organisms are apparently unaffected by pressure, and only a few are unable to grow in oxygen, this method fails for disinfection, and only partially succeeds for preservation.

Carbon dioxide, or "carbonic acid" CO_2, seems to have a special antiseptic and even disinfectant action, inasmuch as aerated waters and beverages have been shown to be in many cases sterilized. Slater[2] has found that this gas in mineral waters has a remarkable effect in killing pathogenic bacteria (typhoid, cholera, *Staphylococcus pyogenes aureus*, Finkler-Prior bacillus). Hochstetter[3] found the same in the case of typhoid, cholera, rabbit septicæmia, *Micrococcus tetragenus*, Finkler-Prior bacillus, *Aspergillus flavescens*, and anthrax bacilli but not anthrax spores.

It is well known that fermented liquors preserved in bottles remain stable for long periods, and this stability seems difficult to explain by the self-exhaustion or deposition of any bacteria present. Bethell in 1848 patented a process for preserving milk, which consisted in first boiling the milk to expel all the air contained in it, and then saturating the liquid with carbon dioxide. The milk when so treated remains fresh for a long time after being opened. Liquefied carbonic acid has also been used for preserving food. Thus, butter when placed in an iron vessel provided with a tap, and subjected to carbonic acid under a pressure of 6 atmospheres

[1] Pettenkofer and Lehmann, *München Acad. d. Wissensch*, 1887, p. 179.
[2] *Journ. of Pathol. and Bacteriology*, 1893, vol. i., p. 468.
[3] *Arbeiten a. d. kais. Gesundheitsammte*, 1887, vol. ii, p. 1.

until all the air has been driven out, remains fresh for four or five weeks, and is not spoiled in flavour or consistency. Carbonic acid may also be injected into whey, giving "a refreshing drink like champagne. The carbonated whey can be enclosed in syphons and will keep for six weeks."[1] This method is quite innocuous, and should be substituted for the use of salicylic or boric acid or glycerine.

J. E. Putzeys, of Brussels, patents an apparatus for purifying water by forcing CO_2 into it and then passing through columns of limestone.[2]

Cyanogen and *hydrocyanic acid* vapour do not seem to be so poisonous to lower organisms as they are to the higher animals. Miquel gives 0·4 of hydrocyanic acid per 1,000 as sterilizing beef-tea. Fumigation with hydrocyanic acid gas is extensively used in America for killing insects in fruit trees. Lowe and Parrott found in June, 1901, that 0·18 gramme of HCN per cub. ft. killed the San José scale without injuring the trees.[3] They conclude that fumigation, where possible, is better than spraying.

Ammonia, sulphuretted hydrogen, sulphurous acid, chlorine, oxygen, ozone, and *oxides of nitrogen* are described under their respective headings.

[1] *Chem. Trade Journ.*, July 15, 1893.
[2] Eng. pat. 21,746, 1901. French pat. 319,060 of 1902.
[3] Bull. New York Agric. Exp. Station, No. 202, 1901.

CHAPTER VI.

METALLIC SALTS.

SALTS OF THE ALKALIES AND ALKALINE EARTHS: Caustic alkalies—Quicklime—Sulphate of lime (Gypsum)—Slaked lime; its use as a precipitant—Sodium carbonate—Acid salts—Ammonia and ammonium carbonate. ZINC: Oxide—Chloride of Zinc—Burnett's fluid—Zinc sulphate, sulphite, and other salts—Various patents. COPPER: Poisonous action—Cuprous chloride—Cupric chloride, nitrate, sulphate, and acetate. IRON: The use of metallic iron for purifying waters—Ferrous sulphate or copperas; the objections to it—Patents and processes—Ferric sulphate and its applications—Ferric chloride—The value of iron salts as disinfectants. MANGANESE: The metal—Manganese peroxide—Manganese salts—Manganates—Condy's fluids—Potassium permanganate—Other permanganates—Mechanical devices—Cost.

SALTS OF THE ALKALIES AND ALKALINE EARTHS.

THE hydroxides of potassium and sodium exercise a sterilizing influence on bacterial growth if they are present in quantities of not less than 2 to 5 per cent.; so do the carbonates in the proportion of 5 to 10 per cent.; the bicarbonates have hardly any action. Miquel classes caustic soda as "moderately antiseptic," stating that it requires 18 grammes per litre to preserve beef tea. He asserts, also, that many other potassium and sodium salts, and especially the sulphates and nitrates when dissolved to saturation in beef tea, are incapable, even in the proportion of 500 per mille. of preventing the germination of bacteria.

In laboratories it is noticed that the development of green *Protococcus* occurs most rapidly in solutions of potassium, calcium, and magnesium sulphates, and sodium phosphate. Calcium chloride solutions also rapidly show growths if exposed to air. Strontium salts do not seem to make any difference. The alkaline acetates and tartrates quickly become mouldy, even in very strong solutions. It will be remembered that all varieties of protoplasm contain salts of the alkalies and alkaline earths; these, therefore, are actually favourable to the life of organisms, and thus are always added to Pasteur's, and other artificial culture solutions.

Sodium chloride and the alkaline sulphates have already been discussed (pp. 97, 137).

Strong brine is often used in washing out milk cans and other utensils, so is washing soda (carbonate) for removing acidity and grease: if strong and warm, the latter is capable of destroying or removing organisms. The addition of a small quantity of salt to milk was formerly more common than at present, as evidenced by the high percentage of ash stated in many early analyses. The chlorine of pure milk, calculated as NaCl, averages 0·13 per cent. with an ash 0·70 to 0·73, but many ashes of 0·8 to over 1·0 per cent. were met with by Dr. Voelcker and others, due probably to the addition of salt or sodium carbonate. The salt was added with a mistaken idea of preservation, but also to increase the flavour so as to cover dilution.

A. Lode shows that even a 50 per cent. salt solution does not kill the spores of common moulds (four species of Aspergillus).[1]

In curing hams the saltpetre is added to affect the colour and taste; it has no marked antiseptic action, although I found that it slightly retarded the souring of milk (Chapter XIV.). Since nitrates are produced by the nitrifying organisms by a process of oxidation, and reduced to ammonia by the growth of other bacteria, and as these latter are very numerous, the nitrates may properly be regarded as salts favourable to the development of many organisms.

The weak antiseptic action of potash and soda may account for the similar slight activity of soap, as the fatty acids do not seem to have any very pronounced antiseptic action.

Sulphate of Lime, on account of its power of absorbing ammonia, is a deodorant, but cannot be regarded as an antiseptic. When used in agriculture it prevents the ammonia from escaping, but does not hinder the decay. It has been a frequent ingredient in mixtures for precipitating sewage; it only acts mechanically, and has the great disadvantage that it adds to the permanent hardness of the effluent water (*Corfield and Parkes*).

Carbonate of Lime, like other insoluble metallic salts, is inert, except in mechanical action.

Quicklime, CaO, is mainly an absorbent; it destroys organic matter by its dehydrating action, and to this cause

[1] *Chem. Centr.*, 1902, xix., 1122.

may be attributed its use for accelerating the decomposition of corpses dead of infectious diseases. There are very few microbes that can remain active any length of time in a dry state, but the bacilli of tubercle have been known to exist in dry dust for more than a year.[1] The *spores* of all known species resist drying for indefinite periods.[2] It is not safe, therefore, to trust entirely to the old method of burying in lime, as, on disinterring, the live spores may again be diffused, unless a very long period has elapsed.

Slaked Lime or calcium hydrate, $Ca(OH)_2$, absorbs acid vapours and sulphuretted hydrogen, and therefore acts to a certain extent as a deodorant. Vallin says[3] that limewash applied to walls is in some degree antiseptic, as it forms insoluble compounds with the organic matter present in condensed pulmonary exhalations. For instance, it coagulates albumen and casein. This would deprive bacteria of food, as shown by the experiments of Pettenkofer, made for the German Cholera Commission of 1879. He concludes that "slaked lime destroys rapidly and completely the organisms of putrefaction; the proportion of $\frac{1}{2}$ per cent. is sufficient for slightly altered bilge-water, but when the putrefaction is strong, 1 per cent. is required. The action on wood and metal is very slight, but the lime removes the odour of the fatty acids of putrefaction, which is often more offensive than that of sulphuretted hydrogen." He mentions as a difficulty the blocking up of pipes and pumps when it is used. The precipitation of sewage by milk of lime was the first process tried by the Rivers Pollution Commission of 1868, and was pronounced to be a failure.[4] In the act of settling, the suspended lime carries down the greater portion of the organisms with other impurities, and renders the water clear. It has been stated also that the lime coats the bacteria and their spores with an insoluble envelope of carbonate of lime. This is the fundamental idea of the Leipzig "Suvern mixture," consisting of quicklime, magnesium chloride, and coal tar or carbolic acid, for sewage. The theory, however, does not seem to have been verified by microscopic examination,

[1] See on the Vitality of Bacilli: Dr. Buchner, *Ohio Sanitary Record*, April, 1894.
[2] Klein, in Stevenson's *Hygiene*, 1893, p. 61.
[3] *Traité des Désinfectants*, 1882, p. 70.
[4] *First Report R.P. Comm.*, p. 52.

and many investigators have proved that, although the changes are much delayed, the water is not sterilized. The liquid is rendered alkaline, ammonia is developed, and, in the case of sewage, the effluent soon again becomes foul.

The State Board of Health of Massachusetts[1] found that it required about 2,000 lbs. of lime to 1,000,000 gallons of sewage to reduce the bacteria to an average of $\frac{1}{100}$ of what they were before. In the same experiments it was found necessary to add alum or aluminium sulphate in addition, to prevent the subsequent distribution of the precipitated microbes in the upper layers.

Numberless experiments on sewage have proved that, although a partial deodorant and a clarifier, lime alone is not an antiseptic, and still less a disinfectant. We have already referred to lime treatment of drinking water in Chapter II.

The use of lime water for preserving eggs depends on the deposition of carbonate of lime in the pores of the shell, rendering it impervious, and also to the lime coagulating the albuminous envelope of the egg.

Knoesel[2] shows that lime decreases the inverting and fermenting power of yeast, and small amounts entirely prevent its multiplication. Milk of lime does not destroy moulds.[3]

Sodium Carbonate, "Washing soda," Na_2CO_3, 10 H_2O. —A strong solution is antagonistic to bacteria, but, as used for clothes, etc., is not effectual without boiling. Reinsch[4] says that 0·1 per cent. of sodium carbonate (Na_2CO_3) caused the multiplication of bacteria, whereas 1 per cent. diminished the number, and 3 per cent. killed them in a sample of the Elbe water from between Hamburg and Altona.

Surgical instruments, after being well washed with soap and water, are frequently sterilized by boiling in a solution of bicarbonate of soda, $\frac{1}{8}$ oz. to the pint. The sodium bicarbonate is added to prevent rusting.

The acid salts of alkalies act by virtue of their acidity, as mentioned under Sulphuric Acid (p. 136). Acid phosphates

[1] *Reports*, 1888-90, vol. xi., p. 737.
[2] *Chem. Centr.*, 1902, xv., 884.
[3] *Arch. Hyg.*, xlii., 107.
[4] *Centr. f. Bakt.*, 1891, vol. x., p. 415.

probably have the most power in this way, but none of them have much value.

Kingzett has made some experiments on the effects of chlorides, nitrates, and sulphates on the growth of mould on flour-paste, and on the putrefaction of extract of beef. His results generally corroborate the statements made above.[1]

Ammonia is a product of the growth of many bacteria, and can therefore only be a restraint on them when it is present in sufficient quantity to kill them by re-imbibition. Miquel classes it as "strongly antiseptic," saying that it requires 1·4 grammes per litre to preserve beef tea.

From the work of Von Rigler and Arnould, ammonia appeared to have a somewhat high efficiency, but Vaillard, who repeated their experiments and bacteriological investigations, concluded[2] that it is not a rapidly efficacious disinfectant and sometimes is quite unreliable, that most bacteria were only destroyed by long action and a large dose, and (with the gas) in a confined space; under such conditions, in short, as do not occur in usual practice.

Ammonium Carbonate, or smelling salts, has a similar action. Miquel mentions ammonium chloride and sulphate as "very feebly antiseptic," the former requiring 115 grammes per litre, and the latter 250 grammes (or a quarter of the weight) to keep beef tea from putrefying.[3]

Zinc.

Clean zinc seems to have an inhibitive effect on vegetable growth, which decreases or disappears when it becomes covered with an oxidized film. Dievert states[4] that when granulated zinc is agitated with water containing bacteria, especially *B. typhosus* and *coli communis*, the water is sterilized in a few hours, even with 5 grammes of zinc to the litre of water. Further experiments showed that the minute quantity of dissolved ZnO formed is not the active agent, though it probably causes a deposition of the bacilli, but that the organisms themselves corrode and dissolve the

[1] *Brit. Med. Journ.*, vol. i., 1888, p. 150.
[2] *Arch. de Méd. et de Pharm. Mil.*, Dec. 1901, p. 441.
[3] Miquel, *Les Org. de l'Atmosphère*, 1883, p. 289.
[4] *Comptes rend.*, cxxxvi., 707.

zinc, by which they appear to be poisoned. Margosches reports that Bayer's method of treating canal waters and industrial effluents with zinc dust, charcoal, and lime, yields in all cases a clear water free from putrefactive bacteria, which, after standing a week, even when mixed with river water, does not undergo putrefaction.[1]

Oxide of Zinc, ZnO, is a white basic powder, and, being slightly antiseptic and emollient, has found favour in ointments.

Chloride of Zinc, $ZnCl_2$, is an exceedingly deliquescent and caustic salt; 10 parts dissolve in 4 of water, 1 in 1 of rectified spirit, 1 in 4 (nearly) of glycerine. Its solution is acid, tastes strongly metallic and astringent, and is very poisonous. Miquel placed it in his class 3 as "strongly disinfectant," stating that 1·9 parts in 1,000 sterilized beef tea. It is one of the most powerful of antiseptics, ranking next to copper sulphate and mercuric chloride. Crace Calvert found that a solution of albumen, to which 1 per mille of zinc chloride was added, required over forty days before germs developed. Koch says[2] that zinc chloride does not act as a germicide, and that even a 5 per cent. solution was utterly useless, but this was based on anthrax spores, which are exceptionally difficult to kill. Dr. Hamilton believes that although it may not kill the germs it may make the surface a barren spot as far as the germs are concerned —*i.e.*, act as an antiseptic. Dr. Richardson made experiments with regard to this salt, confirming, on the whole, the views of Dr. Hamilton. In 1875 and 1876 Pettenkofer and Mehlhausen directed a number of trials in the German Fleet, on the disinfectant value of zinc chloride. Bilge-water of a specific gravity of 1·017 to 1·035, with a slightly alkaline reaction, at a temperature of 20° to 30° C., was treated with a solution of 50 to 60 per cent. strength, in the proportion of 1 part to 100 of bilge. A greyish flocculent precipitate rapidly settled, leaving a nearly clear yellowish liquid. All odour ceased, the organisms seemed to be killed, and the reaction became remarkably acid. At the end of four weeks the mixture showed no signs of change. One

[1] *Leipzig. Monats. Textilind.*, 1901, vi.
[2] *Mittheil. a. d. k. Gesund.*, 1881, p. 234.

part of the solution to 1,000 of bilge caused a decrease of the odour; 2 in 1,000 completely removed sulphuretted hydrogen, much reduced the rancid smell, and preserved the liquid for fourteen days.

A 5 per cent. solution of the neutral salt was found to possess no corrosive action on iron, brass, wood, or caoutchouc. It neither bleaches nor rots ordinary fabrics, but causes a reddening and slight smarting sensation on the skin. The deposit does not clog the pipes or valves of the pumps, as that formed when lime is used. The German Cholera Commission of 1879 prescribed zinc chloride for the disinfection of bilge-water.

In surgery an 8 per cent. solution of zinc chloride has been employed by Sir J. Lister for antiseptic dressings. A solution of 1 to 5 per cent. is sufficiently strong for most purposes.[1]

Sternberg[2] observed that a $2\frac{1}{2}$ per cent. solution destroys bacteria, but a 1 per cent. solution does not prevent inoculation of animals being followed by death. F. Boillat[3] recognized it as a good antiseptic, but found that a 5 per cent. solution did not kill the spores of anthrax. He also showed that it and zinc sulphate coagulate albumen, and that, provided enough of the salt be added to unite with the whole of the albumen, no growth can take place. He considers that Koch only precipitated a part of the albumen, leaving therefore sufficient pabulum for the spores on the threads to develop.

A solution of zinc chloride in the proportion of 1 lb. to 5 gallons of water was patented by Sir W. Burnett (No. 7747, 1838) for preserving timber. A stronger solution, of 40 to 50 per cent., was sold as "Burnett's Disinfecting Fluid," and was extensively used in this country. Dr. E. Parkes strongly recommended it for excreta, especially in military use. Commercially, as being formed by mere deliquescence of the solid, it was of varying strength, up to about 82 per cent. This variability was a great fault, and a definite percentage of zinc or $ZnCl_2$ should always be stated, or the pharmacopœial solution prescribed. *Liquor Zinci*

[1] Vallin, *Désinfectants*, p. 128.
[2] *Bull. N. Board of Health, U.S.A.*, 1881, vol. iii., p. 21.
[3] *Journ. f. praktisch Chem.*, vol. xxv., p. 300.

Chloridi, B.P., 1898, has a sp. gr. of 1·530, and is intended to contain 40 per cent. of zinc, equal to 83·5 per cent. of $ZnCl_2$, but is generally basic, and gives a turbid liquid on dilution. The French Pharmacopœia prescribes a solution of 1 in 6, with 1 per cent. of hydrochloric acid to dissolve the basic chloride.

Among the medicinal preparations are:—*Lotion*, 1 grain of the *Liquor* in 1 oz. of water, or about 1 in 1,000 of zinc chloride (London Ophthalmic Hospital). *Paste*, liq. zinc chlor. and flour, equal parts; glycerine, enough to make a thick paste; an excellent antiseptic for wounds (London Hospital); opium is often added. *Compound powder*, zinc oxide mixed with an equal weight of zinc chloride makes the latter dry enough to blow into cavities. *Points* or *darts* of zinc chloride fused in moulds and kept in glass tubes have been used in the treatment of anthrax.[1] *Compound ditto*, equal weights of the oxide and chloride mixed with 2 parts of flour and water to make a stiff paste, are milder and less irritating.

The official strength for rooms was 1 of the fluid to 100 of water (about 1 of zinc chloride in 200); for sewers and closets half this strength might be used.[2] For excreta a 10 per cent. solution was stirred in, using 1 part to about 9 of the excreta, making about 1 per cent. of zinc chloride present.

"Eau de Saint-Luc," much sold in France, was a concentrated impure solution of chloride and sulphate of zinc, with occasionally some acetic acid. Specific gravity, 1·613; strength, 77 per cent. of zinc chloride. It must not be used without dilution.[3]

Prof. Lamelongue[4] injected small quantities of zinc chloride in tuberculosis to promote induration of the tissue, so as to "encapsule" the bacteria. Dr. Vidal, as an injection for fœtid discharges, employed a solution containing 15 grammes zinc chloride, 1 gramme boric acid, ammonia to just neutralize, and 1 litre of water.[5]

[1] *Brit. Med. J.*, 1887, vol. ii. p. 644.

[2] *B. Med. B. of Health.*

[3] *Vallin*, p. 126.

[4] *Lancet*, July 11, 1891.

[5] *Ibid*, p. 346.

Daudenant patented a process for sewage,[1] using lime, then salts of aluminium and zinc chloride.

This salt is also used for injecting corpses, using 8 litres of a solution of 40° Baumé.

Zinc Nitrate, $Zn(NO_3)_2$, as a disinfectant is inferior to the chloride, and more expensive.

Zinc Sulphate, $ZnSO_4$, $7H_2O$, occurs in transparent crystals, and is less antiseptic than the chloride. Recent investigations by Koch, Klein, and others prove that it is of no value as a germicide. Still it has been a favourite substance to mix with sulphates of copper and mercury, probably from an idea of cheapness, although it is likely that it may add to their action. Patent No. 19,766, 1881, treats sewage with zinc sulphate.

Bierbach states that an article sold as "urinal cakes" consisted of a mixture of the sulphates of zinc, copper, iron, and soda, also some alum with resin, the salts probably being fused with the resin so as to make them dissolve more slowly. Holmes and Emmens[2] propose to utilize the spent liquor of batteries, containing zinc sulphate and sulphuric acid, as a disinfectant. Meillère's disinfectant, used in Paris, for stools in the sick room,[3] contained 1 kilo. zinc sulphate, sulphuric acid 5 to 10 c.c., coloured with 0·15 grm. indigo and scented with nitrobenzene. Five grm. were placed in the bedpan before use.

The disinfectant employed on the Pennsylvania Railway consists of a solution of the chlorides of zinc, mercury, and copper, with a little turpentine to act as a tell-tale. W. T. Sedgwick has tested this mixture upon various typical bacteria, and concludes that its efficiency is due to the mercuric chloride.[4]

"Tuson's Disinfectant" is sulphite of lime with sulphates of aluminium and zinc.[5] It evolves SO_2.

"Radlauer's Antisepsin" contains 85 parts of zinc sulphate, 25 of zinc iodide (a good but caustic antiseptic), 2·5 of thymol, and 10 of boric acid. It is said to be very successful for wounds and ulcers.

[1] Patent No. 4203, 1886.
[2] Patent No. 4,061, 1883.
[3] *Lancet*, 3728, p. 277.
[4] *Tech. Quarterly*, vol. ii., p. 43.
[5] *Lancet*, 1891, vol. ii., p. 19.

Zinc Acetate, 2 grns. to the ounce of water, is used as an antiseptic in ophthalmia and and gonorrhœa.

Zinc Sulphite is insoluble. Tichborne and Henston[1] made an antiseptic gauze by boiling the latter with zinc sulphate, then dipping in hot sodium sulphite solution, and washing. Zinc sulphite, $ZnSO_3$, is precipitated in the tissue.

Acid Sulphite of Zinc is a soluble salt, and its use as an antiseptic has been patented by Boake and Roberts.[2]

Zinc Sulphocarbolate is strongly antiseptic, has no odour, and does not cause irritation. To spray the throat in diphtheria, etc., 5 grns. per ounce is used; for the eyes, 4 grns. per ounce; and for injections, 60 grns. to the pint. These strengths seem very insufficient, but perhaps there is some danger of poisoning.

Rotterine[3] contains 45 grains each of zinc chloride and sulphocarbolate, 27 of boric acid, $2\frac{1}{2}$ of sodium chloride, 6 of salicylic acid, and 1 grain each of citric acid and thymol, all dissolved in a pint of water. It is said to be more effective than 1 per mille of mercuric chloride.

Zinc Salicylate is antiseptic and sparingly soluble. Bovet[4] proposes to antisepticize all houses in the course of building, by incorporating 5 per cent. of zinc salicylate in the plaster, soaking the woodwork with 4 per cent., and the papers and hangings with 1 per cent. He says that the additional expense does not amount to more than 2 per cent. of the total cost of construction.

All soluble zinc salts absorb ammonia and sulphuretted hydrogen, so that they act in that respect as deodorants.

Copper.

The soluble salts of copper have a distinctly poisonous action on bacteria. They coagulate albumen, and combine with most of the organic acids present, to form non-putrescible salts. They absorb sulphuretted hydrogen,

[1] Patent No. 11,985, 1890.
[2] Patent No. 8,509, 1886.
[3] Dr. Rotter, *Chem. and Drug.*, 1889, p. 35.
[4] *Bull. Soc. Mulhouse*, 1890, p. 546.

ammonia, and compound ammonias, and therefore combine with "ptomaines." In fact, copper salts rank next to mercury in power as antiseptics. They are used (Kyan's method) for injecting timber to kill the spores of the fungi (mainly *Merulius lachrymans*) causing dry rot. It is difficult by law to keep them out of pickles and preserved vegetables, as they improve the colour and add to the keeping qualities. In several cases of prosecution under the Food and Drugs Act, for copper in food, it has been adduced by authorities that a small quantity of copper is not injurious.[1] Copper salts are not volatile, their action is, therefore, strictly local. Compared with zinc salts, they share with mercury, silver and bismuth, the disadvantage that any surface washed with them is blackened by sulphuretted hydrogen, whereas zinc sulphide is white. Nevertheless, M. Bureg recommended that curtains, clothing, wood, etc., should be impregnated with copper salts.

Cuprous Chloride, Cu_2Cl_2, is white, almost insoluble in water, but somewhat soluble in dilute hydrochloric acid. On exposure to air it becomes oxidized to cupric chloride, and therefore acts as a reducing agent.

Kroncke[2] contended that for sewage treatment, compounds having a great affinity for sulphur should yield the best results. He has experimented with cuprous chloride as being a salt which fulfils this condition, is readily prepared, very easily removed from solutions, and becomes much less poisonous when oxidized. He used the following method for the purification of water:—Cuprous chloride amounting to $\frac{1}{20000}$ of the liquid to be treated, and ferrous sulphate (as far as possible free from ferric), to the extent of $\frac{1}{4000}$, are mixed with the water. After six hours, $\frac{1}{1000}$ part of lime is added, and agitated for one hour. After settling for one and a-half hours, and filtration through sand, the water, which originally contained 40,000 to 50,000 organisms per cubic centimetre was found to be completely sterilized, clear, almost colourless, and free from iron and copper. The sand filter can be used a long time without cleansing. The cost of purifying is estimated at 1/- per 1,000 cubic metres. He proposed to burn the sediment and recover the copper.

[1] *Journ. Soc. Chem. Ind.*, 1895, pp. 539 and 705.

[2] *Journ. für Gasbeleucht*, vol. xxxvi., p. 513.

Schumburg[1] reports that a water treated with cuprous chloride solution and then with lime, was free from germs after six hours.

Cupric Chloride, $CuCl_2$, occurs as green very soluble crystals. Dr. Green[2] has examined various copper salts as to their relative value as disinfectants. He tried 1, 2½, 5, and 10 per cent. solutions. The test objects were twenty-four-hour-old bouillon cultures of cholera, enteric fever, *Staphylococcus pyogenes aureus*, anthrax free from spores, and spores of same dried on silk threads, besides several mixtures of excreta and urine infected with cholera, etc. The 5 per cent. solutions were in most cases fatal after two hours, but with anthrax only the specimens on the thread were killed, and then only when in contact with a 5 per cent. solution of copper chloride for twenty-seven days, and with the 10 per cent. solution for eighteen days. Weaker solutions only retarded the growth. The general result is that cupric chloride is the most active, and that their relative activity is in accordance with the proportion of copper in the compounds—viz., chloride 1 in 2·7, acetate 1 in 3·1, nitrate 1 in 3·8, sulphate 1 in 3·9. He states that 5 per cent. solutions of copper salts cost approximately the same as 5 per cent. carbolic acid. It is also pointed out that although cupric sulphate is somewhat extensively used as a disinfectant, especially on the Continent, the chloride should take its place as being the better salt to use.

If the above results with anthrax be confirmed, there seems to be considerable risk attending the use of copper salts altogether, as it is impossible to be certain that anthrax or other spores are absent in general disinfection.

Leveson and Slater[3] proposed for purifying sewage the addition of crude aluminium chloride (made by treating shale with hydrochloric acid), then chloride of copper, carbon, clay, and, finally, lime to neutralize the acid and precipitate the metals. This patent is typical of a large number of complicated processes that have been introduced for the utilization of this salt for sewage treatment.

Cupric Sulphate, $CuSO_4$, $5H_2O$, the cheapest copper

[1] *Chem. Centr.*, 1900, ii, 203.
[2] *Proc. Inst. Civil Eng.*, vol. cxiii., p. 42. *Zeit. für Hyg.*, 1893, p. 495.
[3] Patent No. 11,641, 1884.

salt, is soluble in 4 parts of water. To kill bacteria of putrefaction, according to Miquel,[1] a solution of 1 in 111 is required; according to Bucholtz,[2] 1 in 133. Calvert and M'Dougall found that a strength of 1 in 900 prevented the growth of organisms in beef tea for eighty-six days. It may be taken, then, that 1 per cent. is disinfectant, while 1 in 1,000 is antiseptic for most bacteria. Kingzett also noticed that a solution of 0·25 per cent. of cupric or mercuric sulphate prevented putrefaction in broth for sixteen days; the observation did not last longer.[3]

The French authorities (1892) decided to adopt as their official disinfectant, in combating the cholera, sulphate of copper in a 5 per cent. solution, and, specially for the disinfection of rooms, a solution of corrosive sublimate and tartaric acid in the proportion of 1 of the former to 3 of the latter.

Eau Désinfectante Larnaudes, sold in France, contains 20 per cent. copper sulphate and 20 per cent. zinc sulphate.[4] Vallin states[5] that this solution usually contains only a little copper, and that when used as spray on walls and floors, persons entering the room just after the operation notice a marked cupreous taste and the styptic flavour of the zinc salt. Vincent disinfects fæces and the contents of cesspools with acidified copper sulphate, using 6 kilos. per cubic metre per twenty-four hours.[6]

Cohn, in experiments on chicken cholera, considered sulphate of copper and chloride of zinc superior to borax (?) and chloride of lime. But the German government have adopted neither of the former.

Verdigris (cupric acetate) is used as a wash for destroying the parasites of plants, especially *Peronospora infestans*, the potato blight Still better is the copper-lime-sugar wash of Michel Perret.[7] These and the sulphate are also used for soaking seed corn, etc. Hollrung examined a number of

[1] *Les Organismes*, p. 289.
[2] *Arch. exp. Pathol.*, vol. iv., p. 1.
[3] *Lancet*, 1889, vol. i., p. 144.
[4] *Notice de la nettoiement de la voie publique, Paris*, 1876.
[5] *Désinfectants*, p. 62.
[6] *Compt. rend.*, vol. cxix., p. 965.
[7] A. Girard, *Comptes rendus*, 1892, vol. cxiv., p. 234.

fungicides containing copper and soaps.[1] The use of a spray of sulphate of copper for preventing potato rot and improving the cultivation of the tubers has been shown in Ireland to be not without risk. A farmer who had tried to clear an obstruction from his spraying machine by sucking it, narrowly escaped death, and children have been made seriously ill by eating berries which had received the spray.[2]

Fumigation with copper salts does not seem possible, but Clemens[3] proposed a lamp filled with a solution of cupric chloride in alcohol and chloroform, which when lighted is meant to give off vapours of copper chloride. Reichardt[4] pronounced its use to be offensive, poisonous, and variable. Clemens also sprinkled the straw, etc., in stables infected with rinderpest with the same solution. For this it would doubtless be efficient, but the expense would be very great, and the animals must be removed.

Bona[5] proposed a mixture of cupric sulphate and alum under the name of "Cupralum."

"Microsol"[6] is described as a copper sulpho-carbolate, proposed, in a 2·5 per cent. solution, as a "cheap disinfectant" for drains (?). It smells strongly of SO_2.

Iron.

Metallic Iron has long been used as a purifying agent for waters exposed to air. In water free from oxygen, carbonic acid, and chlorides, pure iron can only rust by decomposing the water itself, forming a crust of ferrous oxide which protects the surface, and liberating hydrogen. If oxygen be present the ferrous oxide rapidly turns to red ferric hydrate, still giving a protective coating. But if carbonic acid be also present in excess, it dissolves the ferrous hydrate as ferrous bicarbonate, which in turn is oxidized to ferric hydrate, and the carbonic acid is again free to act on the iron, until the whole of the metal is corroded and the ferric hydrate has deposited as an ochreous sediment,

[1] *Chem. Centr.*, 1899, ii., 628.
[2] *Medical World*, Dec. 17th, 1898.
[3] *Deutsche Industriezeitung*, 1866, p. 268.
[4] *Disinfectionsmittel*, 1881, p. 65.
[5] *Brit. Med. Journ.*, 1875, p. 239.
[6] Fendler, *Pharm. Zeit.*, 1902, p. 599.

leaving the water almost free from iron. The corrosion is hastened through electrolytic action if the iron contains other metals. Chlorides of sodium, calcium, and magnesium are also partly decomposed, nitrates are reduced to ammonia, and alkalinity is developed. At the same time, by the action of bacteria on albuminous substances, or even on sulphates, black sulphide of iron is frequently precipitated, while much iron may also be retained in solution by soluble organic matter. Water is thus liable to acquire a peculiar unpleasant odour, due probably to hydrocarbons, and a styptic ferruginous taste. The iron salts not only exert an antiseptic action of moderate strength, but the ferric hydrate, like alumina, effects the removal of bacteria, and also in the same way "mordants" and precipitates many of the colouring and other organic matters present. By adding lime and allowing to aerate and settle, or by filtration through carbonate of lime and subsequent aëration, the liquid may become colourless and very nearly pure, but sand filtration is generally required.

Among applications of this principle are Bischof's Spongy Iron (patent 3461, 1887), "Carferal" (patent 12,392, 1892)[1] Irving's metallic iron cascades (8056, 1884), patents 4619 and 14,735 of 1891, and Anderson's revolving cylinders (5496 of 1884 and 10,706 of 1891) with scrap iron continually falling through a slow current of water. The latter has long been in successful use at Antwerp, Dordrecht and other places,[2] and was favourably reported on for River Severn water at Worcester in 1892.[3] The electrical processes of Webster and some others also mainly depend on this action of iron, or of aluminium. Frankland proved that metallic iron exerts a special destructive action on bacteria, and pointed out that though bacteria prosper and multiply in sulphurous acid, cyanides, and other poisons, they are, on the contrary, rapidly destroyed by metallic iron.[4]

Several patents do not reduce the oxide to the metallic state, but to the lower oxide, Fe_3O_4. It must be remembered in the use of iron that the metal itself cannot be in

[1] *Journ. Soc. Chem. Ind.*, 1893, p. 539.
[2] *Journ. Soc. Arts*, Feb. 14th, 1896.
[3] *Trans. San. Inst.*, 1892, p. 309.
[4] Letter to the Engineers of the Municipal Council, Paris, 1881, p. 67 of their *Observations*.

contact with the water, or there would be the inevitable unpleasant taste and odour mentioned above. The purification is due to the oxides, which act as carriers of oxygen from the air to the organic matter present, and the core of metal is intended to act as a reservoir of fresh oxides.

Magnetic Carbide[1] consists of iron ore, coke, and sawdust heated together at a red heat in a gas muffle so as to form the oxide Fe_3O_4. The product is then extracted with dilute hydrochloric acid to remove lime, etc.

Magnetic Spongy Iron as used for filters is made from carbonaceous iron-stone (black band) by heating it in closed vessels until all vapour ceases to be evolved.[2] It is also used for sterilizing air[3] and for precipitating sewage. In a later patent iron pyrites is roasted in air and steam, the evolved gases (containing sulphurous acid) passed over ferric hydrate, mixed with bauxite (native alumina) and the residue lixiviated with water. The insoluble portion is then roasted with coal tar, etc., short of the metallic state, crushed, and used with the solution for sewage precipitation.[4]

Carferal (an abbreviation of carbon-ferrum-alumina), already mentioned, is similar.

Rusty scrap iron mixed with peat or wood-charcoal has been protected by Cox and Cox[5] for the treatment of sewage.

Ferrous Sulphate, $FeSO_4$, $7H_2O$, occurs in green crystals, soluble in 1·6 parts of water.

All ferrous salts absorb oxygen from the air, becoming converted into basic ferric salts which deposit as a rusty precipitate, and acid ferric salts which remain in solution. Hence they act as reducing agents. Owing to the formation of "iron-mould," the iron salts are inapplicable for the disinfection of clothing. They deodorize fœtid liquids by absorption of ammonia and sulphuretted hydrogen, but at the same time form a black coating of ferrous sulphide, which slowly passes to brown basic ferric sulphate by absorption of oxygen. This ferric coating can again absorb

[1] Rimmer, Patent No. 8,357, 1887.

[2] Candy, Patent No. 1,793, 1886.

[3] Angell and Candy, Patent No. 14,999, 1887.

[4] Candy, Patent No. 18,598, 1892.

[5] Patent No. 1,259, 1886.

sulphuretted hydrogen, and again be oxidized, and thus acts as a kind of perpetual deodorant.

Virchow has pointed out one of the inconveniences of iron salts. The volatile fatty acids, butyric, valeric, etc., which cause a part of the offensive odour of putrefaction, are commonly combined with ammonia. When iron salts are added the fatty acids are set free or turned into unstable iron compounds, so that the immediate effect of the projection of sulphate of iron into latrines is often an augmentation of the fœtor; this soon decreases, but usually reappears after a time.[1] The same result would accrue on adding almost any acid or acid salt, and thus, as well as for other reasons, it is necessary to supplement the use of an acid, or treatment with an iron salt, by lime. Lake[2] proposes "iron salt, then lime, then filter"; Lockwood,[3] "iron salt, then hot milk of lime"; Conder[4] uses ferrous sulphate for treating water or sewage and (unsuitably) for the preservation of meat.

Deposits of sulphide of iron in sewers may be a source of danger, since they are liable to produce sulphuretted hydrogen on the influx of any acid liquid. An oxidizing disinfectant like chlorine would, however, convert it into a sulphate and allow of its removal. All reducing disinfectants are open to the following objections; (1) they permit the reduced organic matters to be oxidized again by the air; (2) they are themselves in great part at first wasted by the free oxygen of the air and the water; (3) unless kept out of contact with air they lose strength more or less rapidly by absorbing oxygen; (4) the anaerobic bacteria are mostly reducing in their action and flourish readily in surroundings deprived of oxygen, whereas free oxygen is capable itself of killing them and destroying their food. With many organic substances, *e.g.*, tannin, iron salts produce a black colouration, and hence the French administration have prohibited the use of iron salts where pavements or gullies can be discoloured. In December, 1879, a Paris manufacturer recovered heavy damages from a Disinfecting Company for stains on his materials caused by careless disinfection by

[1] Vallin's *Désinfectants*, p. 63.
[2] Patent No. 3,953, 1884.
[3] Patent No. 2,560, 1892.
[4] Patent No. 6,459, 1885.

ferrous sulphate. Vallin significantly adds (p. 75), "It seems that the disinfection was proved by the evidence to have been quite insufficient, whatever may have been the quantity of sulphate of iron employed." Pettenkofer states that for the disinfection of discharges it requires 25 grammes of ferrous sulphate per head per day, or about 1 in 400 on the quantity of excreta. The strength of solution recommended is 28° Baumé or about 37 per cent., of crystallized ferrous sulphate.

Miquel classed ferrous sulphate as "moderately antiseptic," 11 grammes per litre being required to prevent putrefaction of beef juice. This amount agrees closely with that proposed by Crace Calvert, who advocated the use of a 1 per cent. solution.

A memorandum of the British Local Government Board in 1892 says--"A substance generally available in the removal of filth from privies and ashpits, and for application to foul earth and the like, is sulphate of iron (green copperas), either in a strong solution made by stirring the crystals with 5 or 10 times their bulk of hot water, or in the form of powder, to which form the crystals may be readily brought after desiccation.[1] This agent should be used in quantity sufficient to destroy all odour,[2] and in the removal of filth accumulations it should be well mixed with successive layers of the matter to be removed. It cannot confidently be stated that either the iron salt or any available substance will effect a true disinfection of such masses of filth as are here in question."

About the same time the Society of Medical Officers of Health also approved of ferrous sulphate for excreta. The Belgian Government disinfected dejecta with ferrous sulphate (or 2 or 3 per cent. carbolic), obtaining a supply by suspending a bucket containing 50 kilogrammes in a cask full of water.

Germany, Austria, Sweden, and the United States do not officially use it. In Jena, a mixture of 1 part of the salt

[1] By this they lose water of crystallization, which is nearly half (45 per cent.) their weight, and become rather less easily soluble. If overheated a great loss would occur from oxidation and production of a basic salt. So that desiccation is of very doubtful expediency.

[2] See Virchow's remark, *ante*, p. 163.

to 2 or 3 of ground gypsum (which absorbs ammonia) is sprinkled on the drains,[1] and is called "Lüder and Seidloff's Disinfecting powder."

Roth and Lex[2] showed that a mass of fæces treated with a very strong solution of ferrous sulphate developed fungi in abundance.

Ferric Sulphate, $Fe_2(SO_4)_3$, 9 H_2O, in solution is brown and strongly acid. It is moderately antiseptic, an imperfect deodorizer, and is open to the same objections as ferrous sulphate, except that it is not a reducing agent. It has recently been proposed as a cheap non-poisonous disinfectant, and is prepared by the action of sulphuric acid on burnt pyrites, but the solution would contain also some ferrous sulphate in most cases. It has been manufactured into briquettes with plaster of Paris, and sometimes 5 per cent. of phenol. Ferric sulphate gives precipitates with nitrogenous organic matters, and coagulates albumen. Fresh urine treated with ferric sulphate yields a precipitate containing 5·34 per cent. of nitrogen and 12·42 per cent. of phosphoric acid.

It is to be regretted that ferric sulphate, which could be so cheaply made, is not of the value that some statements have implied. It does not kill bacteria unless it be of impracticable strength.

Ferric Chloride, Fe_2Cl_6, is very soluble in water, giving a yellow or brown strongly acid solution. In properties it resembles ferric sulphate, but is said to have a slightly higher power. It is a feeble oxidizing agent, absorbing ammonias and sulphuretted hydrogen. It checks fermentation and the growth of bacteria without killing them, unless it is concentrated.[3] With excreta it is apt to cause a very nauseous odour. Wernich gives a favourable account of its action as a precipitant:—"Putrid and offensive materials containing ammonium carbonate cause a precipitate of iron oxide which carries down the suspended matters; the supernatant liquid is clear, and both it and the precipitate are inodorous, the sulphuretted hydrogen being removed as ferrous sulphide

[1] Reichardt's *Disinfection*, 1881, p. 100.

[2] *Handb. d. Militar.*, vol. i., p. 524.

[3] Frankland and Ward's Second Report, *Journ. Soc. Chemical Industry*, 1893, p. 1,052.

and free sulphur, and the ammonia turned into ammonium chloride."[1] Sternberg says that it quickly paralyses the power of infection, which, however, after a time revives.[2]

Drs. Hofmann and E. Frankland, in a report to the Metropolitan Board of Works in 1859, recommended chloride of iron for the deodorization of sewage, and found that to deodorize 7,500 gallons, $\frac{1}{3}$ gallon of perchloride of iron was equivalent to 3 lbs. of chloride of lime or 1 bushel of lime. The first of these kept the tank free from odour for upwards of nine days, whilst the lime treatment broke down on the third day, and that with bleaching powder after five days.

Vallin condemns it as a disinfectant.[3] It has no official recognition.

Iron salts have been much used in the treatment of sewage, but the bactericidal action which was formerly aimed at is, as we have seen, practically non-existent. Duyk has recently advocated using a mixture of ferric chloride and chloride of lime for water purification. The solution he calls "ferrochlor" and shows that its oxidizing properties are due to free hypochlorous acid and ferric acid, FeO_3.[4]

Manganese.

The metal is at present commercially unavailable for water purification; it would act like metallic iron, but with greater energy. "Ferro-manganese," an alloy containing up to 80 per cent. manganese, and "Spiegeleisen" might be useful substitutes for iron in water purification.

Peroxide or Dioxide of Manganese, MnO_2, found native as Pyrolusite, does not yield its oxygen to organic matters at the ordinary temperature. The precipitated peroxide (hydrated) is also sluggish. Yet a large number of proposals are existent for the use of the mineral alone as an oxidizer, as for example Candy's patent,[5] which asserts that "sewage may be purified by agitation in a suitable vessel with granular manganese dioxide, the average time of contact being about five minutes." Under these conditions, and

[1] *Disinfections Lehre*, 1882, p. 180.
[2] *Nat. B. of Health, U.S.A.*, 1881, vol. cxi., p. 4.
[3] *Désinfectants*, p. 65.
[4] *Chem. Centr.*, 1903, i. [20] 1100.
[5] Patent No. 15,391, 1891.

also in filtration through the crude oxide, the mechanical action is practically the only effect. If pyrolusite be heated strongly in closed vessels with carbon, a mixture of the excess of carbon with lower oxides of manganese, or perhaps the metal itself, is obtained. By this treatment the carbon is at the same time purified and deprived of its hydrogen and any tarry product which may be present. Such a preparation is much more active as a carrier of oxygen than the similar one made with oxides of iron, and does not, like iron, yield metal to the water. "Manganous carbon" was introduced by Bernays.

This oxide when heated with hydrochloric acid is the ordinary source of chlorine—

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

As mentioned under the halogens, if it be heated with a chloride, bromide, or iodide and sulphuric acid, it gives off the whole of the chlorine, bromine or iodine. Such mixtures have been much used for disinfecting rooms (*ante*, p. 77).

Manganous Salts.—The chloride, $MnCl_2$ and sulphate, $MnSO_4$ are slightly antiseptic. Miquel calls the former a weak antiseptic since he required 25 grammes of it to prevent growths in a litre of beef tea. Page considers that these salts are good disinfectants, but adduces no experiments in support of his conclusion. Slater, Page, and others[1] proposed manganese chloride and sulphate for sewage treatment, either alone or mixed with salts of aluminium.

Chloride or sulphate of iron mixed with vitriol or hydrochloric acid, manganese dioxide, or hydrated ferric oxide, and ground bauxite,[2] is an example of the mixtures of iron, manganese, and aluminium salts formerly advocated for sewage treatment.

Manganous salts as such may be excluded from the list of useful disinfectants, antiseptics, or even deodorants. They do not oxidize on exposure to air, and, therefore, do not act as carriers of oxygen. Even if lime be added, so as to precipitate manganous hydrate which is re-oxidized by air, the action in presence of much water and organic matter is unsatisfactory, and the expense would be great.

[1] Patent No. 3,973, 1886.
[2] *Chem. Trades Journ.*, Feb. 25th, 1893.

Manganates and Permanganates.—The manganates of the alkalies are dark-green, unstable salts; they are produced by fusing potash or soda, or their carbonates, with manganese dioxide in the presence of air, or with an oxidizing agent, such as potassium or sodium chlorate or nitrate. Impure sodium manganate, Na_2MnO_4, with much sodium chloride, is known as "Condy's Green Fluid"; it also contains some permanganate (if barium chloride be added, the manganate is precipitated, and the crimson permanganate is left in solution), and is strongly alkaline from excess of the base. It is a cheap oxidizer, but as being impure and of varying strength, is much less used than the permanganate. It spontaneously gives up 1 atom of oxygen with great readiness, turning brown and turbid from the precipitation of the hydrated peroxide thus—

$$Na_2MnO_4 + 3H_2O = 2NaOH + Mn(OH)_4 + O.$$

If a dilute acid be added, even carbonic, it changes the colour to crimson, forming the permanganate, while hydrated peroxide is again precipitated, thus with the K salt—

$$3K_2MnO_4 + 2H_2SO_4 = K_2Mn_2O_8 + Mn(OH)_4 + 2K_2SO_4.$$

The decanted solution of impure permanganate is nearly neutral, and is known as "Condy's Red Fluid." If evaporated it yields crystals of permanganate,[1] which are purified by re-crystallization. An application of this reaction is made in J. C. Stevenson's patent[2] "acid sodium sulphate, ground with crude sodium manganese, gives permanganate when dissolved."

Stevenson and Tatters[3] use dry sodium manganate 6 parts, bleaching powder 3 parts; this yields a mixture of manganate, hypochlorite, and chloride. Dupré and Hake[4] propose "a manganate with magnesium sulphate or kieserite, calcium sulphate, zinc sulphate, or boric acid. The manganate and one of these reagents are mixed in a dry fine state of division."

Manganate of soda added *in sufficient quantity* to sewers at different points, destroys organic impurity, and by treatment at the outfall, the effluent may be made perfectly

[1] The K salt is used for this as it crystallizes better.
[2] Patent No. 2,739, Feb. 1885.
[3] Patent No. 381, Jan., 1887.
[4] Patent No. 4,283, 1887.

odourless, so as to be safely discharged into streams. Being strongly alkaline, it disengages ammonia, which is removed at the outfall by ferrous sulphate or acid. On this principle manganates were used by the Metropolitan Board of Works, and by the London County Council, with fair results. In Reeves' system of disinfecting sewers, sodium manganate treated with sulphuric acid in an earthenware apparatus placed in the manholes, gives oxidizing vapours of permanganic acid, while the solution overflows into the sewage.[1]

The strengths of two commercial fluids, as determined by Allen in 1872, were—

	Green.	Crimson.
Available oxygen in grammes per litre,	3·883	3·921

Potassium Permanganate, $K_2Mn_2O_8$, occurs in dark-red needles, which are permanent in the air, and soluble in 15 or 16 parts of cold water, giving an intensely crimson solution. In contact with organic matter, when acidified with sulphuric acid, it can furnish 5 atoms of oxygen—

$$K_2Mn_2O_8 + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 3H_2O + 5O.$$

The solution should remain clear. If the acid be insufficient, a brown precipitate of hydrated peroxide falls, and then only 3 atoms of oxygen are liberated—

$$K_2Mn_2O_8 + H_2SO_4 + 3H_2O = K_2SO_4 + 2Mn(OH)_4 + 3O.$$

The progress of the reaction can be watched by the loss of colour of the permanganate, the final point, when excess is reached, being sharply indicated by the persistence of the pink colour. Its disadvantages are:—

1. It leaves a brown stain on fabrics, and if concentrated it corrodes them.

2. Like oxidizers generally, it must first expend itself in oxidizing sulphuretted hydrogen, nitrites, ferrous salts, and most organic matters, before attacking organisms, which are so resistant to it, that Koch states[2] that it is applicable only in concentrated solutions (5 per cent.). Miquel put it in the third class of disinfectants, requiring 3·5 grammes to sterilize 1 litre of beef tea. Calvert, on the other hand, found that

[1] *Rideal on Sewage.* 1901, p. 154. *Journ. Soc. Chem Ind.*, 1902, p. 925.
[2] *Mitth. a. d. kais. Ges.*, Dec. 3, 1881.

1 in 125 "prevented animalcules in beef juice and albumen for six days." Hankin considers it a specific for cholera bacilli.[1]

3. Not being volatile, it can only act locally. Condy in 1859 proposed its employment for air-disinfection by hanging up sheets saturated with the solution, by sprinkling walls, and by exposing layers of it in dishes in infected rooms. By such procedure a large quantity of air must escape contact with the liquid.

The solid when treated with strong sulphuric acid gives off ozone, but the reaction is a violent one, and is dangerous in inexperienced hands.

Demarquay spoke favourably of it for surgical use in a solution containing 1 in 1,000, as disinfecting very well, and as hardly irritant. But its action is rapidly exhausted, and it does not prevent the secretions from retaining their virulence, and Vallin is of the opinion that it is of more value as an immediate deodorant than as a destroyer of virus.[2] This statement has since been corroborated by Blyth,[3] and by Klein.[4]

4. Permanganates do not absorb ammonia, and do not attack urea nor fatty acids.

Condy and Mitchell's original patent has long expired. In 1877 the former invented a very ingenious contrivance with vertical threads hanging close together in a ring, down which a solution of permanganate trickled from a circular basin above to a similar one below. This, of course, could be applied to other disinfectants; with volatile ones it would be more effective.

Among the numerous patents employing permanganates for disinfecting purposes are:—Reidemeister of Magdeburg[5]; "small quantities of potassium permanganate and peroxide of hydrogen are added to water, when a bulky precipitate forms, carrying down all suspended matter and the smallest organisms, while oxygen is evolved."

Tweedie and Hartin's "Crimson Salt"[6] is 1 part of

[1] *Brit. Med. Journ.*, Mar. 16, 1895.
[2] Vallin, *Traité*, pp. 325-328.
[3] "Studies of Disinfectants by New Methods," *Proc. R. Soc.*, 1886.
[4] Stevenson and Murphy's *Hygiene*, 1893, p. 61.
[5] German Patent, July, 1882.
[6] Patent No. 9,538, June, 1884.

potassium permanganate, 8 of potash alum, 1 of borax, 6 of sodium chloride. H. B. Condy[1] proposes the use of the aluminium salt: "In 1,000 parts by weight of a 33 per cent. solution of aluminium sulphate, dissolve 53 of potassium permanganate by heat. On cooling, potash sulphate alone crystallizes out, leaving permanganate of alumina and excess of aluminium sulphate in solution."

Lumps for closets containing the following mixture have been proposed:—Boric acid 10, salicylic acid 10, potassium permanganate 40, potassium or sodium silicate 40, made into a hard mass.[2] Meyer uses "Dry powdered barium permanganate 25 parts, to sodium bi-sulphate 16 parts, mixed in the dry state; an inert body like barium sulphate may be added to give bulk. If sufficient water be added to form a thick syrup, ozonised oxygen will be evolved."[3]

Hamilton[4] fuses potassium chlorate, manganese dioxide, and potash, saturates the solution with carbonic acid, and crystallizes. This is simply an old method of making permanganate. He then mixes it with borax.

"Taylor's Roylat Disinfector" is a contrivance for liberating the liquid in cisterns automatically. Stoneware bottles are filled with permanganate and closed, with the exception of a small glass tube which reaches to the bottom. The bottle is inverted in the cistern, and when the latter empties some strong solution flows out.[5] Wade's is a syphon arrangement for the same purpose.

"Condy's powder" contains a small proportion of alkaline permanganate and has no smell.[6]

Disinfecting tablets or blocks have been proposed by Thornton.[7] They are "prepared by mixing potassium permanganate or other disinfectant, paraffin wax, sulphate of calcium, or any other suitable cement, with some absorbent

[1] Patent No. 10,015, 1884.

[2] *J. Soc. Chem. Ind.*, 1890, p. 98.

[3] Patent No. 16,463, 1888.

[4] Patent No. 6,571, 1887.

[5] *Cf.* a similar method for cisterns, by B. S. Proctor, *Chemist and Druggist*, April 28, 1894; also Patent 5238 of 1902.

[6] *Lancet*, 1887, p. 683.

[7] Patent No. 17,421 1891.

material, such as asbestos, cotton yarn, pumice-stone, cinders, etc.

"Permanganate of potash is mixed with plaster of Paris or other cement or plaster, and cast into bricks or balls or into perforated tin cases, the object being to economize the permanganate."[1]

One or two patents propose to recover the manganese or iron oxides precipitated in the sludge in sewage treatment, by pressing the latter, adding more ferric or manganese oxide, if necessary, heating in a closed retort, utilizing the ammonia and evolved gases, cooling out of contact with air, and using the mixture of carbon with metallic oxides as a filtering medium.[2] The process, however, is not economical, as there is so much water to remove, and the product is of very inferior value.

M'Dougall calculated that "at the commercial price of Condy's fluid in his time, it would cost £10,400 per annum to disinfect with permanganate the typhoid stools of a hospital having an average of 30 cases." Urine and fæces reduce such a large quantity that the expense of sterilizing with permanganate the 24 hours excreta of one person has been estimated at 20 shillings. Crystallized permanganate has been much cheapened, but the cost yet remains sufficiently formidable to prevent its extended use, and, as already pointed out, its applications are somewhat restricted.

[1] M. Syer, Patent No. 11,049, 1892.

[2] Wilson, Patent No. 17,275, 1891, and others.

CHAPTER VII.

METALLIC SALTS *(continued)*.

ALUMINIUM SALTS: Use in Sewage Precipitation—Alums—Aluminium Chloride—"Chloralum"—Acetate—Sulphites—General Character of the Salts. CHROMIUM: Chromic Acid—Potassium Bichromate. ARSENIC: Arsenious Acid—Arsenites—"Paris Green"—Arsenic Acid—Prohibition in France. LEAD and its Salts: Nitrate and Acetate. MERCURY: Oxide and Nitrate—Corrosive Sublimate; its power as a Disinfectant—Applications—Iodide—Mercuric Iodide Soaps—Cyanide—"Zinc Mercuric Cyanide"—Objections to Mercury Compounds—Organic Mercurials. TIN: Stannous Chloride. BISMUTH: Subnitrate—"Dermatol." SILVER: Nitrate of Silver—Organic Silver Preparations—Osmic Acid. GENERAL REMARKS ON DISINFECTANTS.

ALUMINIUM.

THE soluble salts of aluminium generally are powerfully astringent, acid, styptic to taste, and in solutions of moderate strength are not poisonous. They also produce no stain on fabrics and are inexpensive. On addition of lime or ammonia they give a bulky flocculent precipitate of hydrated alumina, carrying down mechanically with it not only the solid matter in suspension and any germs that may be present, but also much of the dissolved organic matter, forming more or less definite combinations analogous to the "lakes." They have, therefore, been most extensively tried for sewage, both alone and with iron salts, lime in most cases being added. The effluent by this treatment is in general found to be clear, nearly free from colour and odour, and deprived of most of its organisms. Unless an equivalent of lime or ammonia is present, the precipitation is incomplete, the liquid becomes acid and has an injurious influence on fish. The precipitate or "sludge" should include all the phosphates, most of the nitrogenous matter, and, since it contains no poisonous disinfectant, be available commercially as manure, a point that has encouraged a large number of disappointing processes.

The antiseptic power of the alums and of aluminium sulphate, the forms most commonly used, is only slightly greater than that of the sulphuric acid they contain, and as the

removal of organisms is only partial, the effluent soon becomes again foul, and on being diluted by passing into rivers, is capable of contaminating immense volumes of water. That the whole of the river is not polluted is often due to the fact that "purified" sewage does not readily mix with ordinary water, but flows on for long distances in a separate stream.

The "sludge" also becomes quickly offensive in warm weather. Repeated attempts to utilize it as manure, by straining, pressing, drying, and even fortifying with phosphates, etc., have hitherto met with only partial success.

Attempts to burn it for cement, utilizing the ammonia and other gases evolved, have also been made. The great difficulty is the removal of the water, which gives in the drying, and still more in the burning, offensive vapours.

An analysis by the author of a sample of "alumino-ferric," used for sewage treatment, gave the following results:—Ferric oxide 0·91, alumina (soluble) 15·65, SO_3 37·00, water 46·44.

A report by Lepoins, published by the Frankfort Commission on Sewage, 1891, states as follows:—"The effect of chemical precipitation is not so greatly superior to the purification obtained by simple deposition in tanks, as to warrant the adoption of any of the above processes in preference to simple mechanical treatment."

The result of trials at the St. Lawrence Experimental Station in Massachusetts has shown that "a mixture of lime and aluminium sulphate has little to recommend it."

Sir R. Rawlinson[1] remarked, "To disinfect the sewage of the Metropolis would cost millions per annum, and, according to Dr. Parkes, the most powerful disinfectants would not give safe results. 'Clarification' may be accomplished temporarily by chemicals, but will not then produce permanent purity. It will cost £1,500 to £3,000 for each million gallons per diem, and even the less amount will reach £225,000 per annum for the Metropolis, while expenses will raise this half a million." Within the last few years chemical precipitation of sewage has in the

[1] *Journ. Soc. Arts*, vol. xxxviii., p. 65.

majority of places been abandoned and replaced by modern bacterial methods.

Aluminium Chloride, Al_2Cl_6, occurs in white crystals, very soluble in water, strongly acid, non-poisonous, but powerfully astringent when diluted; it absorbs ammonia and compound ammonias, but not sulphuretted hydrogen, therefore it is only a partial deodorant. It is more antiseptic than the sulphate, and still more than alum. Miquel gives the minimum for sterilizing a litre of beef tea as Al_2Cl_6 1·4, potash alum, 4·5 grammes, as compared with mercuric chloride 0·07, copper sulphate 0·9, and zinc chloride 1·9, so that its behaviour is intermediate between copper sulphate and zinc chloride. The ordinary crystals contain $12H_2O$.

A preparation of aluminium chloride was introduced under the name of "chloralum." Neither this nor "cupralum," (p. 160), however, met with success.[1]

Aluminium Acetate has been much praised by Barow, Kuhn, Wernitz, and Jalan de la Croix. It would doubtless be useful for surgical dressings, but is unnecessary and unsafe as a disinfectant. Maas recommends a 2·5 per cent. solution for surgical work.

Aluminium Sulphites have been recommended by Wade as non-poisonous and non-irritating antiseptics.[2]

Chromium.

Chromic Acid, CrO_3, is a powerful oxidizer, and instantly coagulates albumen. It combines with a great many organic compounds, producing brown or yellow substances. This staining or mordanting action causes it to kill bacteria by an action on their envelopes, but its cost and poisonous and corrosive nature have excluded it from the list of useful disinfectants.

Potassium Bichromate, $K_2Cr_2O_7$, is similar, but less vigorous in its properties.

The earlier investigators made many experiments with these two agents,[3] but most of the trials were not under conditions of actual practice.

[1] O'Neill, *Army Med. Report*, 1871. Vallin, *Désinfectants*.

[2] *Pharm. Record*, Nov. 1, 1888.

[3] *Med. Times and Gaz.*, 1872, p. 485: *Army Med. Report*, 1872, p. 202: *Gaz. Med.*, 1874, p. 44.

Lanjorrois[1] to 500 cubic centimetres of urine and blood added 5 grammes of bichromate, and found that in eight months there was no putrescence. He does not say whether any coagulation of the latter occurred. Milk with 1 per cent. of bichromate remained unaltered for three months. But owing to their poisonous action chromates should not be used as preservatives. According to A. Leys, however,[2] the use of alkaline chromates for this purpose had become frequent on the Continent in 1898, the most common proportion being 1 part in 100,000.

Kidd patented a mixture of potassium or sodium bichromate, or chromic acid, with a little sulphuric acid, for disinfecting sewage. Even if efficient, the expense would be prohibitive.

Arsenic.

Arsenious Acid, As_2O_3, is a white powder, slightly soluble in water (about 1 in 1,000), giving a feebly acid, and almost tasteless yet strongly poisonous solution. It dissolves, however, very easily in alkalies forming arsenites, and is also soluble in hydrochloric acid as arsenious chloride, or "liquor arsenici hydrochloricus."

Although arsenic is so powerful a poison to higher animals and insects, it has little effect on lower forms of life.[3] Miquel ranks As_2O_3 as "moderately antiseptic," requiring 6 grammes per litre to prevent growth in beef tea.

"Gannal's solution" for injecting corpses contained 21 grammes of As_2O_3 and 1,000 grammes of aluminium sulphate per litre. A dangerous occasional practice was to sprinkle seed with As_2O_3 before sowing, to kill fungi and insects.

Potassium Arsenite, "Fowler's solution," and Sodium Arsenite, have long been employed as "Sheep-dips," for killing insect parasites. Robertson patents the following preparation[4]:—"3 of rosin, 1 of grease melted with 6½ tar oil (containing 25 per cent, tar acids), and 2 of 95 per cent.

[1] *Chem. Centr.*, 1884, p. 676.
[2] *J. Pharm. Chim.*, 1899, x., 337.
[3] Frankland and Ward, *Journ. Soc. Chem. Ind.*, 1893, p. 1,053.
[4] Patent No. 2,990, 1893.

phenol. Add 2 of arsenious acid dissolved in 1½ per cent. soda-lye, or an equivalent quantity of arsenic sulphide may be used. The product is soluble in cold water, and has the properties of a simple carbolic dip and an arsenic dip, the tar acids coagulating the parasites, and the arsenic having a continuous poisonous effect on their progeny."

Knoesel[1] found that a moderate quantity of sodium arsenite destroyed the propagating and fermenting power of yeast.

Acetoarsenite of Copper, "Paris Green," contains 28·5 per cent. of arsenic and 32 per cent. of copper. It is insoluble, but is one of the best agents for killing insects on trees, sprayed over them in the proportion of 1 ounce to 10 gallons of water.

Arsenious Sulphide, As_2S_3, dissolved in alkaline sulphides, is used in tanning to prevent fermentation and putrefaction. But S. Sadlon says[2] that common salt, together with an alkaline sulphide, will produce the same result. A substitute for arsenic is highly desirable.

Arsenic Acid, H_3AsO_4, is much more soluble, and reputed to be more poisonous, than arsenious acid. But neither it nor the arsenates are of any value as germicides. Miquel states that the potassium salt is "very feebly antiseptic," requiring 125 grammes per litre to prevent growth in beef tea, while sodium arsenate is "moderately antiseptic," requiring 9 grammes per litre.[3] Loew[4] remarks that "the acids of arsenic are poisonous towards algæ only in the same degree and for the same reason as are acetic and citric. Larvæ and infusoria live in a 1 per mille solution of potassium arsenate, though higher animals die."

In France the use of arsenical compounds as antiseptics has been totally prohibited since 1876. Considering the ease and rapidity with which arsenic is diffused, and the insidious action, even of traces, in water, food, or air, even if it were a good antiseptic, its use in this connection should be penal in all countries.

[1] *Chem Centralblatt*, 1902, xvi., 943.
[2] *Der Gerber*, 1891, vol. xvii., p. 284.
[3] *Les Organismes*, p. 289.
[4] *Centr. f. Agric. Chem.*, vol. xiii., p. 68.

Lead.

Lead salts absorb sulphuretted hydrogen, ammonia, and their derivatives, and are therefore deodorant. Measured by the amount required to sterilize a litre of broth, Miquel classes them as "strongly antiseptic," only slightly below zinc chloride; where 1·9 grammes of the latter are used, 2 grammes of lead chloride, or 3·6 grammes of lead nitrate, are required.

Nitrate of Lead, $Pb(NO_3)_2$, is the basis of a "disinfectant" long known under the name of "Ledoyen's liquid," composed of 1 part of the salt in 10 of water. M. Fermond in 1858 used it in the closets of the Salpetrière, and found it was effective in removing the odour, as other metallic salts would be, but it had the disadvantage of being easily precipitated as lead sulphate, and of covering the basins with a black coating of lead sulphide. It is expensive, and does not absorb ammonia readily. It is inapplicable for wounds, on accounts of its ready absorption and poisonous effect on the system.

Basic Acetate of Lead, or "Goulards' Extract," is used for burns and bruises, but only for its cooling qualities.

In conclusion, lead compounds are of no value as disinfectants.

Compounds of Mercury.

The metal in minute subdivision in lard forms the preparation *unguentum hydrargyri*, used in syphilis and in parasitic skin diseases: it contains 40 to 50 per cent. Hg with generally a small proportion of oleate.[1]

Mercuric Oxide, HgO, like insoluble substances generally, has no action by itself on organisms, but it easily dissolves in even vegetable acids to form many soluble, and therefore active, salts. Admixed or combined with phenol, it has been used for a "carbolate of mercury" soap, which, according to Dr. Woodhead,[2] is not a valuable preparation. Combined with oleic acid it forms a strongly anti-parasitic basis for ointment. Oleate of mercury is in the British and most other pharmacopœias.

[1] *Pharm. Journ.*, [3] xv., 230.
[2] *British Med. Assoc. Reports*, 1888.

Mercuric and Mercurous Nitrates are strongly antiseptic soluble salts, but are not used because they are caustic and are easily decomposed by a large quantity of water. "Unguentum Hyd. Nitratis" is a parasiticide.

Mercuric Chloride, $HgCl_2$, perchloride of mercury, or "corrosive sublimate," is probably the most powerful disinfectant we possess. It will be seen that the poisonous action of a great number of antiseptics depends on their property of precipitating albumen and other allied ingredients of protoplasm. For example, phenol, mineral acids, copper and iron salts, alum, tannin, chromic acid, all form insoluble compounds with albumen. Mercuric chloride possesses this property in a very marked degree, but the compound produced re-dissolves in excess of albumen. It is, therefore, necessary to have mercuric chloride present in excess. Mercuric chloride dissolves in 15 parts of water, and is more soluble in alcohol, ether, ammonium chloride, sodium chloride, and dilute acids. It is exceedingly poisonous, a dose of 2 centigrammes daily soon producing toxic effects; this almost prevents its use internally, and even makes its external employment dangerous. Hence solutions of it used for disinfection should be coloured, preferably blue. In the United States it is recommended to add an equal quantity of potassium permanganate to distinguish the solution. As to the efficiency of mercuric chloride, the earlier investigators gave varying but very high results. Bucholtz, in a comparative list of the amounts of different disinfectants required to suppress the growth of bacteria in culture solutions, places mercuric chloride in the foremost place, and recommends a solution of 1 in 20,000.[1] Miquel says that a solution of 1 in 14,000 is disinfectant, and Sternberg 1 in 30,000. Koch asserts that "a single application of a solution 1 in 1,000 or even 1 in 5,000 is sufficient to destroy the most resistant organism in a few minutes; with a longer exposure it only begins to be unreliable at 1 in 20,000."[2] Davaine[3] stated that 1 in 15,000 killed anthrax, and Vallin that 1 in 2,500 is effective under most unfavourable

[1] *Archiv. f. exp. Pathol.*, vol. iv., p 80.

[2] *Mittheil a. d. k. Gesund.*, 1881, p. 234.

[3] *Bull. de l'Acad. de Méd.*, July 1880.

circumstances.[1] Billroth, Haberkorn, and Kuhn likewise recommend it. Therefore, though it cannot be employed for preserving food on account of its poisonous nature, it has been used for injecting corpses and by most governments for local disinfection. Dr. Collingridge, in a private communication, informs me that for ships' crew's spaces, rooms, etc., after fumigation by sulphur either by the ordinary process of combustion or by the liquid sulphurous acid, he washes with a solution of mercuric chloride of 1 in 2,000. Vessels entering the Mississippi suspected of contamination are sprayed over all surfaces excepting the cargo with a solution of 1 in 1,000.[2] The hold is then disinfected with sulphur. Since mercuric chloride is non-volatile at ordinary temperatures, it cannot affect the air throughout the spaces, hence it only acts as a strictly local disinfectant.

Recent experiments show that the disinfecting power of mercuric chloride varies with the amount of dissociation and concentration of the metallic ions in the solution. The addition of sodium chloride to a solution of this sort by reducing the amount of dissociation diminishes its disinfectant power. This is, of course, more marked in strong solutions, as in very dilute solutions the free ions are the more numerous.[3]

Klein very much reduced the former too favourable estimates of the power of this salt. He considers it an efficient germicide, but maintains that Koch and others have over-rated it. In 1885 Blyth conducted a series of experiments in which he treated anthrax spores with 1 in 1,000 solution of mercuric chloride, as others had done, when he noticed that the bacteria were apparently killed and the spores ceased to develop; but on then inoculating guinea-pigs with the apparently sterilized infusion, anthrax rapidly appeared, the animals died, and the blood was swarming with *Bacillus anthracis*. He concluded that a solution of 1 in 1,000, although it kills the non-spore-bearing organisms, only stupefies and does not destroy the spores of *Bacillus*

[1] Vallin, *Traité*, p. 117.

[2] *Pharm. Journ.*, 1887, p. 144.

[3] *Pharm. J.*, 1900, lxv., 339-343, 363-368; also see a paper by Harrington and Walker on the Reaction Time of Corrosive Sublimate in different dilutions against various Bacteria, *Boston Medical Jour.*, U.S., April 23rd, 1903.

anthracis.[1] Dr. Woodhead[2] explains Klein's results as due to the precipitation of the mercuric chloride by the albumen present, "which gave a coating or pellicle of albuminate of mercury round the spores, protecting them from further action until they were introduced into the blood of the animals, when the excess of albumen re-dissolved the pellicle and set the organism free to flourish in its new surroundings."

Crace Calvert also pointed out, many years ago, that mercuric chloride "destroys vibrios but not fungi"; and H. Schulz[3] has shown that a solution of 1 in 500,000 increases the activity of *Saccharomyces cerevisiæ*. Lode, in experiments with four species of Aspergillus, proved that 0·25 per cent. prevented their growth, but that the 1 in 1,000 solution required 10 to 60 minutes to destroy the spores.[4]

Koch repeated his experiments and somewhat modified his earlier conclusions. He still affirms that mercuric salts, especially the chloride, are most valuable. "For a ship's bilge, where a 5 per cent. solution of carbolic acid must be left for forty-eight hours, a 1 in 1,000 mercuric chloride solution only required a few minutes." He admits that "there is on the other hand reason for doubting the efficacy of this salt, for though anthrax spores subjected to a 1 in 20,000 solution for ten minutes and then washed in alcohol gave no growth in nutrient gelatine, silk threads infected with the spores and then exposed for ten minutes to a 1 in 20,000 or even 1 in 10,000 solution proved fatal to mice."[5]

Herroun considers that the value of this substance as an antiseptic has been very much over-rated, as he has cultivated ordinary septic bacteria in albuminous filtrates containing 1 in 20,000 of mercuric chloride. "It is precipitated by albumens if used in greater strength, and is readily converted by the sulphur of all bodies into insoluble mercuric sulphide which is practically inert." It may be remarked also that mercuric chloride is precipitated by any alkaline solution such as ammonia, etc. Laplace in a series of experiments found that 5 c.c. of blood serum was sufficient to

[1] *Micro-organisms of Disease*, 1886, p. 261.
[2] *Proc. Roy. Soc. of Edinburgh*, vol. xv., p. 246.
[3] *Pfluger's Archiv.*, vol. xlii., p. 517
[4] *Chem. Centr.*, 1902, I., xix., 1122.
[5] Crookshank's *Bacteriology*, 1887, p 150.

precipitate the mercury from 5 c.c. of a solution of the strength of 1 in 1,000, but that by adding hydrochloric acid in the proportion of 5 in 1,000, the formation of the precipitate is prevented. Similar results are obtained when tartaric is substituted for hydrochloric acid.[1] When about 10 parts of sodium chloride are added to 1 of mercuric chloride, the coagulation of the albumen is also prevented.

It may be concluded that Klein's results are confirmed, and that Woodhead's explanation is at any rate part of the truth. It follows that the minimum must be raised to 1 in 500, and that the solution should be acidified, preferably with about ½ per cent. of hydrochloric acid, which adds much to the bactericidal power. If, as already mentioned, permanganate is used with it, or some colouring matter like indigo or aniline blue be added, the advantage of the warning colour is obtained. In the United States mercuric chloride is held in great esteem. Dr. Mead Bolton[2] gives the following table of the minimum strength required of various disinfectants:—

Organism.	Chloride of Lime.	Mercuric Chloride.	Carbolic Acid.
Typhoid bacillus, . .	1 in 2,000	1 in 10,000	1 in 100
Cholera spirillum, . .	1 in 2,000	1 in 10,000	1 in 100
Anthrax spores, . .	1 in 100	1 in 1,000 (?)	1 in 50 (?) (Uncertain).
Staphylococcus aureus, .	1 in 200	...	1 in 100
„ *citreus*, .	1 in 50	...	1 in 100
„ *albus*, .	1 in 200	...	1 in 100

I have found in my own experiments that 1 in 2,000 of mercuric chloride destroys *B. coli communis* in less than 15 minutes with only a small amount of organic matter present.

The American Public Health Association recommend a solution of 1 in 500 of mercuric chloride to be used for spore-containing infected material, and 1 in 2,000 for that which does not contain spores, as compared with 5 per cent. carbolic or 10 per cent. zinc chloride. Hands are washed in a 1 in 1,000 solution. The dead are wrapped in sheets saturated with 1 in 500; walls are washed with 1 in 1,000,

[1] *Brit. Med. Journ.*, 1888, p. 148.
[2] *Report of Comm. on Disinfectants of Amer. P. H. Assoc*, 1889, p. 236.

and ships sprayed liberally with the same strength. According to Rosenau, sea water is extensively used at the seaport quarantine stations for making bichloride solutions, as the 4 per cent. of NaCl which it contains much aids its solvent power.

The French authorities adopt a solution containing 1 gramme of mercuric chloride and 3 of tartaric acid in 500 of distilled water for disinfecting rooms (Laplace's formula).

In Paris, spraying rooms after infectious disease with a 1 in 1,000 solution of mercuric chloride by means of a "pulverisateur," has found much favour during the last few years, and the results obtained are said to be highly satisfactory. No bad effects have followed this practice in Paris, although 35,000 houses were disinfected in this way in 1893, and considerably more in 1894. In Berlin, this practice is not recommended, and in India cases of salivation have been attributed to the use of a mercuric chloride solution as a disinfectant wash for floor boards.

A clause of the Italian Sanitary laws applied to railways directed that:—"The whole inside of the carriage is to be repeatedly brushed over with a 2 per mille solution of sublimate. Cattle trucks are to be thoroughly washed with a solution of carbolic acid, or an equivalent disinfectant, and with corrosive sublimate when animals suffering from a contagious disease have been in the trucks." It is to be noted that mercuric chloride solution, especially if acidified, rapidly injures cushions or hangings. The late Dr. Thorne, of the British Local Government Board, believed corrosive sublimate, so far as cholera is concerned, to be its most potent germicide. The official circular issued by Sir G. Buchanan in April, 1888, was confirmed by the Board in 1892. The following method is recommended:—"For the purposes of the sick room, such as reception of soiled handkerchiefs, sheets, and the like, as well as for the swabbing of floors, a valuable disinfectant solution may be made with perchloride of mercury. It is well to have this solution slightly acid, coloured also in such a way that it shall not readily be confused with drinks or medicines; and proper caution should be given to avoid accidents in its use. Sanitary authorities will find it advantageous to have such a solution prepared under the direct instructions of the

medical officer of health, and supplied at a uniform strength at the infected house by the order of that officer. A solution fitted for the desired purposes may be made with half an ounce of corrosive sublimate, 1 fluid ounce hydrochloric acid and 5 grains of commercial aniline blue, in 3 gallons (a bucketful) of common water. It ought not to cost more than threepence the bucketful, and should be further diluted. The use of non-metallic vessels (wooden or earthenware) should be enjoined, and articles that have been soaked in it should be set to soak in common water for some hours before they go to the wash." The strength of the above solution is 1 in 960; it should be 1 ounce of mercuric chloride, or about 1 in 500.

The following means of colouring disinfectant solutions have been proposed:—Corrosive sublimate—Methyl violet, 1 drop 5-per-cent. solution to the pint; Nicholson's blue, 1 drop 1-per-cent. solution to the pint; indigo carmine, 25 drops 1-per-cent. solution to the pint; malachite green, 3 drops 1-per-cent. solution to the pint. Carbolic acid—Fuchsine, 1 drop 1-per-cent solution to the pint; eosine, 5 drops 1-per-cent. solution to the pint; safranin, 2 drops 1-per-cent. solution to the pint. These colours are fairly permanent and distinctive. It has been suggested that an international scheme of colouring should be arranged.

Dr. C. T. Williams, of Brompton Hospital, stated that mercuric chloride did not interfere with the tubercle bacillus and from Schill and Fischer's experiments it appeared doubtful whether mercuric chloride, even in the proportion of 1 in 500, could destroy tubercle bacilli in phthisical sputa. Experiments at Netley[1] indicated that with 1 in 1,000 solution, at least 12 hours' exposure should be allowed for the complete destruction, and even then the reagent must be well mixed with the infected matter. "Not less strength than 1 per cent. was necessary to destroy the spores of anthrax and B. subtilis. One part of sublimate in 5,000 of gelatine is antiseptic, or sufficient to inhibit the growth of most micro-organisms." Ratimoff[2] gives a table of comparative values of disinfectants, and cites experiments showing that amounts

[1] Notter and Firth's *Theory and Practice of Hygiene.*

[2] *Bied. Centralblatt*, vol. xiv., p. 360.

of mercuric chloride from 1 in 13,300 to 1 in 800,000 killed, in his experiments, various infective organisms, which results are at variance with those of other observers. Dr. A. Ivert in 1889 treated forty-five cases of Asiatic cholera in Tonquin, with mercuric chloride internally, in doses of ·02 to ·04 gramme per twenty-four hours. The death-rate among these was 20 per cent., whereas the general death-rate was not less than 66 per cent. He also tried it as a prophylactic agent, and in no case did any signs of cholera develop.[1] F. A. Coward[2] gave mercuric chloride (and tinct. ferr. perchlor.) internally in sixty cases of diphtheria, in some cases also spraying the throat with a solution of mercuric chloride, glycerine, and potassic chlorate. He states that all were successful, even without the spray.

Solutions of the strength of 1 in 1,000 to 1 in 10,000 have been for many years used as antiseptic dressings by surgeons and by dentists. If strong, the mercury will be absorbed, causing salivation, and local irritation may also be produced. The formation of an insoluble mercuric "albuminate" with the serum exuding from a wound is apt to throw the mercury out of action. In Laplace's solution this is prevented by adding tartaric acid to the liquid (see p. 183); but Drs. Lubbert and Schneider found that the acid caused irritation to wounds, therefore they use a solution containing mercuric chloride 2 parts, sodium chloride 100, distilled water 600, glycerine 100, rectified spirits 200, to prevent the albuminate precipitating.[3] Dr. Wilson's solution is 1 of mercuric chloride, 1 of ammonium chloride, and 1,000 of water.[4] The "St. Bede Disinfectant," made at Newcastle-on-Tyne, consists chiefly of sodium sulphate, mercuric chloride, and a little sulphuric acid, formed into blocks with indigo, eucalyptus, and thymol.[5] "Antiseptin," a name already appropriated, is a mixture of 2 parts of an alkaline silicate, and one part of 0·1 per cent. solution of mercuric chloride.[6]

[1] *Comptes rendus*, vol cvii., p. 695.
[2] *Brit. Med Journ.*, 1891.
[3] *Chem. and Drug.*, 1893.
[4] *Pharm. Journ.*, 1891, p. 960.
[5] *Lancet*, vol. ii., 1889, p. 701.
[6] L. J. Paulsson, *Zeits. Oesterr. Apoth. Verein*, xxxiv, 555.

"Chlorol" is the misleading name given to a solution of mercuric and sodium chlorides, "to which copper sulphate is added as an emetic in case of accidental swallowing."[1]

M. Balmé has invented an antiseptic paper in the shape of perforated sheets like postage stamps, made into a book. A white unsized paper is employed, as it is found not to reduce the mercury and lose strength as gauze does. In the manufacture, on to each sheet is dropped from a pipette a known quantity of a standard sublimate solution. When dry they each contain an exactly known amount of the agent, and only require to be moistened and applied to the wound.[2]

"Sublimate gauze," as used in the German Army, contains about 1 in 200 or 300 of $HgCl_2$, and is coloured pink by magenta to distinguish it. "Sal alembroth" (ammoniomercuric chloride) gauze is also made coloured with aniline blue.

It has been mentioned that distilled water should be employed for making up sublimate solutions, since the carbonate of lime in ordinary water causes a precipitate. If distilled water be unattainable, the difficulty can be avoided by adding an acid, as in the English and French prescriptions. An alternative is the addition of an alkaline chloride, ordinary salt being generally chosen. Victor Meyer considers these precautions to be unnecessary, since he found that a 1 per 1,000 solution of mercuric chloride made even with a bad pond water, kept well in the dark for two months.[3]

C. J. Bond[4] recommended a pellet containing $4\frac{1}{2}$ grains of mercuric chloride and $4\frac{1}{2}$ of sodium chloride which can be dissolved in a pint of water in about three minutes, forming a solution of 1 in 2,000. Solutions made with salt do not turn milky with hard water like those with ammonium chloride.

Vignon[5] points out that as a definite strength is of the utmost importance, the permanence of the liquids must be secured. He noticed that a 1 per mille solution of mercuric

[1] Helbing's *Modern Materia Medica*, 1895, p. 35.
[2] *Chem. and Drug.*, 1889, p. 110.
[3] *Ber.*, vol. xx., p 2,970 (1888).
[4] *Chem. and Drug.*, Aug. 9, 1890.
[5] *Comptes rend.*, 1893, Dec. 4.

chloride in pure distilled water becomes slightly turbid in from twenty-four hours to two or three days, and gradually gives a white precipitate. He obtained the following results:—

	Mercuric chloride per litre (in solution).
Original solution, ...	1·00 gramme.
Open to air for 7 days (volume reduced by evaporation from 500 to 385 c.c., and, therefore, solutions should become stronger),	0·57 ,,
In a closed flask for 7 days, . . .	0.97 ,,
In a closed flask for 220 days, . . .	0·67 ,,

Colouring matters diminish the loss, indigo being better than fuchsine (because the former is acid), but still there is a loss under the best circumstances from 1·00 to 0·98 in 7, and to 0·80 in 220 days. The alkaline chlorides generally help the keeping power. Solutions with 10 grammes of sodium, ammonium, or potassium chloride to 1 gramme of mercuric chloride, keep practically unaltered for a very long time. One per 1,000 of hydrochloric acid acts in the same way, but has an irritant effect.

It is evident that the weakening is due to dissociation, a basic chloride precipitating and an acid remaining in solution. Exposure and heating cause the hydrochloric acid to be volatilized. The double salts are more stable, therefore 1 per cent. of salt, or 10 per cent. of hydrochloric acid, should be added in making up the solution. The sublimate dissolves more readily when it is finely powdered and well agitated with the liquid, as it is sparingly soluble and rapidly settles.

Even neutral mercury solutions corrode iron, and rot zinc and lead from the formation of alloys.

Mercury Albuminate, the white flocculent precipitate given on mixing mercuric chloride with dilute albumen, is non-putrescent, insoluble in water, but soluble (while moist) in sodium chloride, and in excess of albumen, therefore in blood, serum, etc. Gauze impregnated with it is a slow, but mild and effective mercurial antiseptic.[1]

Mercuric Iodide, HgI_2, made by precipitating a mercuric salt by potassium iodide, is scarlet, insoluble in water,

[1] Schneider, *Pharm. Centralblatt*, 1888, p. 141.

but easily soluble in excess of potassium iodide, to form a double salt, potassio-mercuric iodide. This has lately come into use as a disinfectant, being said to have "double the bactericidal power of corrosive sublimate, while it is less poisonous." It was first suggested by Dr. Bernardy, of Philadelphia,[1] and has been patented in France and England by Collin and Benoist.[2] They used 1 part of mercuric iodide to 1 part of potassium iodide. "5 to 15·5 grains are added to a litre of the animal or vegetable liquid to be preserved. Solids are treated with a solution of 15·5 grains per litre (1 in 1,000) for twelve to twenty-four hours, when the germs are all destroyed." They also mention mixing it with eucalyptus and other substances. It is asserted that a solution of this compound of 1 in 4,000 is equivalent to 1 in 2,000 of mercuric chloride. "For washing floors a solution of 1 in 4,000 should be employed, for disinfecting the hands 1 in 2,000, and for instruments 1 in 2 to 3,000."[3] Steel instruments would be attacked unless immediately rinsed.

The solid compound is manufactured under the name of "Iodic Hydrarg.," and is stated to dissolve without decomposition in an equal weight of water, and to be readily soluble in oils.[4] It is recommended by Waschejewsck for ophthalmia in a strength of 1 in 5,000. "It does not precipitate albumen nor cause irritation, and can even be given internally in doses of a quarter grain." It has also been compressed into tablets of definite weight. One soloid of "Hydrarg. Perchlor." in a pint of water gives a solution of 1 in 1,000. Two of "Iodic Hydrarg." in the same quantity give a strength of 1 in 4,000.

P. K. Bolshesolsky[5] strongly recommends a 1 in 10,000 solution of this salt as an antiseptic in obstetrical and surgical practice.

Thomson proposes as an antiseptic, 1 to 3 of mercuric iodide and 1 to 3 of potassium iodide to 100 of soap. The solution for use contains 1 of mercuric iodide in 4,000 of

[1] *Brit. Med. Journ.*, 1887, p. 789.
[2] Patents, Nos. 15,766 and 16,935, 1887.
[3] *Brit. Med. Journ.*, 1887, p. 789.
[4] *Chem. and Drug.*, 1885, 597.
[5] *Proc. Arkhangelsk Med. Soc.*, 1894, vol. ii., p. 191.

water. Dr. Woodhead has experimented on it with favourable results.[1] See also Antiseptic Soaps, Chapter XIII.

Mercuric Cyanide, $Hg(CN)_2$, is soluble in about 8 parts of water, slightly acid, and inodorous. The basic or oxycyanide, $Hg(CN)_2$, HgO, is similar, but slightly alkaline. Both are antiseptic and very poisonous. Solutions of the latter, 1 in 15,000 strength, do not seriously injure instruments, only slightly precipitate albumen, and are tolerated by wounds and by the mucous membrane. Chibert[2] found when he added it to peptonized broth that it had six times the antiseptic power of the chloride, although it does not act so powerfully on *Staph. pyog. aureus*. It has also been found of service in case of diphtheria, and in ophthalmic practice in $\frac{1}{2}$ per cent. solution.[3]

Stellden[4] reports on 1,400 cases of diphtheria treated with this remedy, when only 5 per cent. of deaths occurred, as compared with the ordinary 92 per cent. in that district at the time. (Honey, 450; tinct. aconite, 30; Hg $(CN)_2$, 0·3 grain; also a gargle of 1 $Hg(CN)_2$ in 10,000 of Aq. menth. pip.). Frequent doses and applications were said to suppress the bacillus.

Zinc Mercuric Cyanide.—Lord Lister introduced this compound in 1889. To a solution of potassio-mercuric cyanide, a zinc salt is added; the bulky white precipitate is washed with water till the washings are almost free from mercury, then drained, triturated with starch, ground with potassium sulphate to aid the pulverization, and carefully dried. To fix it on gauze, 3 to 5 per cent. of it is suspended in a 1 in 4,000 solution of mercuric chloride, and the gauze dipped with agitation. The powder keeps when dry, but the gauze must be prepared when required, and used moist.

B. Dott[5] cast some doubts on the definiteness of this compound, questioning the presence of mercury in any quantity. Dunstan[6] proved that the original precipitate, which he prepared by a variety of methods, was a true

[1] *Brit. Medical Association*, Edinburgh Meeting, 1888.
[2] *Compt. rend.*, vol. cvii., p. 119.
[3] *Pharm. Journ.*, 1896, ii., 19. *Therap. Gazette* (Philadelphia), 1896, 405.
[4] *Merck's Bull.*, vol. i., pp. 28-40.
[5] *Lancet*, vol. ii., 1889, p. 1133.
[6] *Chem. Soc. Journ.*, 1892, p. 666.

double salt of the formula $Zn_4Hg(CN)_{10}$ or $HgCN_2$, 4 $Zn(CN)_2$, but that it was decomposed in the washing, the soluble $Hg(CN)_2$ being removed, and the insoluble $Zn(CN)_2$ remaining, so that the result was a mixture of variable composition consisting mainly of zinc cyanide, with, in different samples, 6, 8·5, 10, and 18 per cent. of $Hg(CN)_2$—that is, about a $\frac{1}{4}$ to $\frac{1}{8}$ of what it should be. Long washing or hot washing removes all the mercury.

However useful this preparation might have appeared, the variation in its composition militates against uniform results. Dunstan tried to prepare it in alcohol and other ways, but without success.

Mercuric Chloro-amide, $HgNH_2Cl$, is the insoluble white powder well known as "white precipitate," much used for killing *Pediculi*.

The *potassium thiosulphate* double salt, 3 $Hg(S_2O_3)_2$, 5 $K_2S_2O_3$, and the *pyroborate*, $Hg\ B_4O_7$, have been recommended as antiseptics (Helbing).

The following organic mercurial compounds are all antiseptic and have varying disinfectant powers. All are poisonous. They are occasionally used in emulsified lotions or injections, or in ointments and gauze, against syphilis:

Carbolate, $(C_6H_5O)_2Hg$ (*Szadek*), Sulphocarbolate, and Benzoate (*Stukowenkow*) are white powders, almost insoluble in water. "Hydrargyrol," according to Gautrelet,[1] is a phenylsulphonate of the composition $C_6H_4OHSO_3Hg$, in brownish scales giving with water a red solution. He states that 1 in 250 completely stops the growth of organisms and that it is 75 times less toxic than corrosive sublimate, while it is neutral, precipitates alkaloids and basic toxins, but not albumen. "Hermophenyl," a sodium-mercury phenol sulphonate, is said by Lumière and Cherrotier, in solutions in 1 : 500 to 1 : 200 strength, to be fatal to B. typhosus, pyocyaneus, subtilis, lactis, and Staphylococci in 5 minutes, and to have several surgical advantages.[2]

Salicylate (*Silva-Araujo and Szadek*) in pills, one-sixteenth to one-eighth grain, and as an injection in 0·4 per thousand solution for gonorrhœa and syphilis, has perhaps been more widely used than any other of the newer compounds of mercury.

[1] *Apoth. Zeit.*, 1897, 852.
[2] *Bull. Comm.*, xxix., 225.

Thymolate $(C_{10}H_{13}O)Hg.\ HgNO_3$, Thymolacetate, and Thymosulphate, one-twelfth to one-sixth grain in pills, were recommended by Kobert for syphilis, and by Tranjen for tuberculosis.

Tannate, greenish-brown insoluble scales; 1 to 2 grains have been recommended as an antisyphilitic by Lustgarten, but it is unstable, and the *gallate* has been suggested as better (Helbing).

Imidosuccinate $(C_2H_4(CO_2)_2N)_2Hg$, is soluble in 25 parts of water. One-fifth grain is used hypodermically in syphilis (*Von Mering and Vollert,* 1888).

Naphtholate and Naphtholacetate are condemned by Iaddosohn and Zeissing as producing pain.

Peptonate and "Glutine-peptone sublimate," made by acting on gelatine with hydrochloric acid and adding 25 per cent. of mercuric chloride, are met with in 1 per cent. solution for injections, and are said to be almost painless and to be rapid and efficient (*Dr. Hufer*). The doses are about equal to $\frac{1}{6}$ grain of mercuric chloride.

Schering claims[1] a new class of antiseptics with alkaline reaction, made by combining mercury salts with organic bases. They are said to have no toxic or irritant action, and not to coagulate albumin, so that they can be used in more concentrated solutions than mercuric chloride.

Any surfaces washed with a mercury salt will soon be blackened with sulphuretted hydrogen. Organic matter is liable to reduce and throw the mercury out of action. Ordinary mercuric solutions are compatible with peroxide of hydrogen, acids, permanganate, zinc and copper salts, glycerine, phenol, and most aromatic compounds, but not with borates, sulphites, phosphates, carbonates, or alkalies, which precipitate them.

Compounds of various Metals.

Tin—Stannous Chloride (protochloride of tin), $SnCl_2$, has been suggested as a disinfectant.[2] It is comparatively safe, and does not corrode lead pipes. A solution containing 1 per cent. kills spores after an exposure of two hours.

[1] Patent 5,981 of 1900.

[2] *Year-Book of Pharmacy,* 1887.

When kept for use it should be mixed with an equal quantity of ammonium chloride, which prevents the formation of the insoluble oxychloride of tin.

It is difficult to see any advantage in its introduction, as its bactericidal powers are feeble, and chiefly due to its hydrochloric acid. It would absorb ammonia and sulphuretted hydrogen, like many other agents.

Bismuth.—Gayon and Dupetit[1] were the first to point out that salts of bismuth, even in small quantities, completely prevented the secondary fermentations which take place in worts, but they have not been used to any large extent. L. Defour and Daniel find that the addition of 1 in 10,000 of bismuth subnitrate to cider prevents, or materially retards, the "hardening" of the beverage on exposure to air, besides rendering alcoholic fermentation more complete.[2]

"Orphol"[3] is a bismuth compound of β-naphthol, recommended as an internal antiseptic: 2 to 10 grains. Iodogallate of Bi,[4] or "Airol," is an insoluble grey-green powder said to be an efficient antiseptic. "Crurin" is a quinoline-bismuth sulphocyanide, stated to be even more powerful.[5]

Bismuth subgallate, $C_7H_7O_7Bi$, formed by the action of bismuth nitrate on gallic acid, is soluble in water, alcohol, and ether, and has been introduced under the trade name of "Dermatol." F. Rohrer[6] says of it, "This new disinfectant in the different forms of purulent inflammation of the outer and middle ear, also in affections of the nose, has lately claimed to be a great success. A bacteriological test, in which dermatol mixed with broth or gelatine was infected with anthrax, has revealed, however, that it is not a germicide, and does not even retard the growth. In fact, the bacillus actually changes the dermatol, which becomes yellow, and finally black. The same discoloration occurs in the ear." So that it simply acts as an astringent.

[1] *Comptes rendus*, vol. ciii., p. 883.

[2] *Ibid*, cxxv., 1125.

[3] Colmer, *Allg. Med. Central Zeit.*, 1896, No. 96.

[4] Frizzi, *Repert. de Pharm.* (3) vii., 221; Thibault, *J. Pharm. Ch.*, 1902.

[5] *Therap. Monats.*, 1900, No. 1.

[6] *Centr. f. Bacteriol.*, 1892, vol. xii., p. 625.

Colosanti and Dutto, on the other hand, report favourably on its use as an internal disinfectant.

Silver Nitrate in distilled water is certainly bactericidal, and was classed by Miquel as equal to mercuric chloride, while Lode proved that it was superior in destroying moulds.[1] But the fault of a large number of these metallic solutions is that they are so generally precipitated and rendered inert by common water or by ordinary organic fluids. Silver nitrate in addition is reduced by light. In the author's laboratory B. coli communis was killed in 24 hours by 0·1 per cent., but the same strength failed to kill Staph. pyogenes aureus in the presence of only a small quantity of chloride and organic matter. In diluted urine the former organism was not destroyed by the addition of 0·4 per cent. silver nitrate.

Credé reported favourably on the surgical and bacteriological value of silver salts. Dr. A. Tilger speaks highly of silver citrate, "itrol," as a non-irritant antiseptic dusting for wounds.[2] "Actol" is silver lactate and has special uses.

A number of organic silver salts have been used in place of silver nitrate because they did not, like the latter, form insoluble compounds with albumen. Among them "Argonine," or caseinate of silver, and "Argentamine," a solution of silver phosphate in ethylenediamine, have been studied bacteriologically by Mayer,[3] who finds that with organisms in albuminous solutions the disinfecting power of argonine 1 : 750 is equal to that of silver nitrate 1 : 1000 and that of argentamine 1 in 4,000. The addition of ammonia to argonine considerably increases its efficiency.

"Collargol," or colloidal silver is prepared for use as an antiseptic by a method described by Danlos and Cothereau.[4] It contains 97 per cent. of silver and is soluble in 25 parts of water, but is easily precipitated and not diffusible.

Protargol[5] is a soluble compound of silver (8·3 per cent.) and proteids, introduced by A. Eichengrün, which is not decomposed by acids, and is said to be strongly bactericidal

[1] *Chem. Centr.*, 1902, xix., 1122.

[2] *Münchener Med. Wochen.*, Feb. 9th, 1897; *Charlott. Med. Journal*, April, 1897, p. 474; *Pharm. Centr.*, xxxviii., 460.

[3] *Zeits. f. Hyg. u. Infect.*, 1895, xx., 1.

[4] *Nouv. Remèdes*, xv., 472; xix. (2) 30; *Journ. Soc. Chem. Ind.*, 1903, p. 315.

[5] *Zeits. Oest. Apoth. Ver.*, 1898, 625.

and to be valuable as an antiseptic for wounds. *Largin* is similar, contains 11·1 per cent. Ag, and is destructive to gonococci. *Nargol* contains 10 per cent. Ag.[1]

Osmic Acid is a very powerful bactericide, as mentioned by Klein and supported by Koch. Koch says that Silver and Gold compounds are all inhibitory on tubercle, especially Gold Cyanide, $Au(CN)_3$, dissolved in potassium cyanide; 1 part $Au(CN)_3$ in 2,000,000 parts of solvent checking the growth of tubercle bacillus.

With reference to compounds generally, in view of the search for new disinfectants, it may be mentioned that—

1. As free acids, even the weakest, such as acetic and carbonic, retard, as a rule, the growth of bacteria, which usually require a slightly alkaline medium, the acid salts and those of the metals which have an acid reaction retard putrefaction by virtue of their acid constituent, independently of the nature of the metal.

2. Some metallic salts precipitate albumen—*e.g.*, those of mercury, copper, and most of the heavy metals. Such, by coagulating protoplasm, must kill the organisms, if they can penetrate deep enough. With these salts, disinfection is, therefore, a condition of quantity and time.

3. These metallic salts, and some other substances, such as lime, alumina, phosphates, and charcoal, may starve bacteria by withdrawing, or rendering insoluble, their food.

4. The borates, aromatic substances generally, and a few other compounds exert a direct toxic influence on organisms which, as far as known, is physiological and not chemical. Given sufficient quantity and time, they may actually kill the bacteria and so act as real disinfectants, but they usually only retard the growth, and therefore are chiefly used as antiseptics. Some of them form loose compounds with protoplasm which interfere with its vital functions.

5. Reducing agents, such as sulphites and ferrous salts, withdraw oxygen, which element is necessary for the growth of most organisms.

6. Oxidizing agents, like ozone, peroxide of hydrogen, the halogens, and permanganate, act on bacteria by destroying their food, poisoning them, and finally completely

[1] *Zeits. Oest. Apoth. Ver.*, xxxvi., 256; *Charm. Centr.*, 1900.

destroying them. When this can be carried out, it yields an ideal condition of sterility, nothing to grow, and nothing to feed on. It remains solely to find the minimum required, and then to use a little more for safety. But I have given reasons, under Chlorine, p. 93, why these agents in practice often fail.

7. A few easily reducible metallic salts are fed on by the organisms, which assimilate one of the elements, to be deposited in their tissues as coloured granules, distinctly visible under the microscope. Silver, gold, and some iodine compounds are examples. After a time this deposition chokes, and finally kills them. Probably this accounts for the fact so often observed, that very minute percentages of many poisons actually promote the growth of organisms, which larger amounts destroy. Ordinary therapeutics furnish many parallel instances.[1] Richet remarks[2] that, although very small quantities of certain metallic salts retard or wholly prevent the development of the lactic ferment in milk, still smaller quantities even act as accelerators of the fermentative action.

This explains the absolute necessity of working quantitatively in disinfection, and also many of the discrepancies and misstatements which exist in the literature of the subject.

Richet observes in addition,[3] that the ferment appeared indifferent to salts of copper and mercury in quantities inferior to ·00025 gramme per litre; in doses of ·0005 gramme per litre these salts possessed an accelerative action, and in quantities of 0·001 per litre their antiseptic properties first became evident. The toxic action of the metallic poison does not appear to affect the chemical activity of the ferment, but rather its powers of multiplication. The biological relations as regards the toxicity of metals seem not to follow chemical laws, as certain metals which are chemically very similar have a very different toxicity, and it is especially noteworthy that the rarer metals, to which the ferment is probably not so well accustomed, appear more toxic than the common metals. The prohibitive dose of zinc is 1

[1] Note Crace Calvert's observation under *Mercury*, p. 181; Dr. Williams, *ibid.* p. 184.

[2] *Comptes rendus*, 1892, p. 1494.

[3] *Loc. cit.*

gramme, whilst 0·15 gramme of cadmium sulphate completely prevents fermentation. Ferric and manganese salts are also less toxic than cobalt and nickel salts.

While calcium salts are constituents of food, barium and strontium in the same series give poisonous compounds. Among the rarer metals may still be found a stronger antiseptic than any yet examined.[1] It would appear that in a series of similar metals the higher the atomic weight the more toxic the salts. In the case of the non-metals the reverse may be the case, but at present there is want of data for ascertaining how far the periodic law of the elements bears on their antiseptic and disinfectant action.

B. Krönig and T. Paul, in recent investigations of the relations of chemical disinfectants to bacteria, with special reference to Ostwald's researches on solution, have arrived at the following conclusions:—

(1) Comparative tests should be made with equi-molecular quantities, as a "percentage" is unreliable in precise research.

(2) The disinfecting power of metallic salts depends not only on the properties of the salts, but on those of the solvent and on concentration.

(3) The effect of the compounds of mercury with halogens varies in proportion to their degree of dissociation. The power of aqueous mercuric chloride solutions is diminished by the addition of hydrochloric acid or of other haloid salts, probably owing to the retarded electrolytic dissociation; that of mercuric nitrate, sulphate or acetate, is materially increased by a moderate amount of sodium chloride.

(4) Acids disinfect in proportion to their electrolytic dissociation, that is, in proportion to the concentration of the hydrogen ions, while the bases, potassium, sodium, ammonium, and lithium hydroxides, are active in proportion to the concentration of the hydroxy-ions in the solution. Hydrogen ions are more powerfully toxic for anthrax spores and staph. pyogenes aureus than hydroxy-ions at the same concentration.

(5) The disinfecting power of the series, chlorine, bromine, and iodine, decreases in the ratio of increasing atomic weight (see *ante*, p. 83).

[1] *Vide* Drossbach, German patent 94,734.

(6) Nitric, chromic, chloric, persulphuric and permanganic acids disinfect in proportion to their rank in the series of oxidizing elements arranged according to their electric properties. Chlorine has a very strong specific disinfecting effect.

(7) The disinfecting power of oxidizers is greatly increased by the addition of haloid acids, *e.g.*, hydrochloric acid to a permanganate (probably because the halogen has a tendency to be liberated—see p. 78).

(8) In confirmation of Scheurlen, they find that the presence of mineral salts increases the activity of phenol solutions.

(9) With reference to the influence of the solvent, they find that substances dissolved in methyl or ethyl alcohol, or in ether, are almost without effect on anthrax spores, and that the general disinfecting power of aqueous solutions of phenol and formaldehyde decreases with any addition of methyl or ethyl alcohol. On the other hand, the action of aqueous silver nitrate and mercuric chloride is intensified by definite amounts of ethyl alcohol (50 per cent. for $AgNO_3$, 25 per cent. for $HgCl_2$), methyl alcohol, and acetone. As previously known, the presence of broth, gelatine, or similar organic media, diminishes the disinfecting power of aqueous solutions of metallic salts.

(10) They draw a distinction between the *antiseptic* value, or power of preventing the development of bacteria, and the germicidal energy, or power of killing both matured organisms and spores, and find that the former factor bears no necessary relation to the latter.

This work thus confirms the view that different agents should be selected according to the object in view, whether preservation or disinfection. The above researches were mainly executed with the non-spore-bearing S. pyogenes aureus, and with sporiferous anthrax, in pure solutions; so that although they are of great interest as elucidating some conditions of ideal disinfection by chemical agents, the conclusions are only of limited applicability to practical use.

CHAPTER VIII.

ORGANIC SUBSTANCES.

Coal Tar and its Products: General Account—Tar Water. Hydrocarbons (Neutral Tar Oils): Benzene—Toluene—Naphthalene—Anthracene—Naphthalene Urinal Cakes—"Lauraline." Petroleum. Phenols. Phenol or Carbolic Acid: Properties—Variation in the Commercial Strength—Carbolic Fumigation—Antiseptic Power of Phenol—Not a safe Disinfectant—Uses and Dangers—Objections to the employment of Phenol—Prescriptions in Different Countries. Carbolic Powders: McDougall's—Calvert's—Mayor's—Phenolith—Other Patents. Surgical Preparations: Carbolized Oil—Gauze—Carbolic Wool—Danger of Phenol in Surgery—Carbolic Soaps—Tooth Powders—Various Preparations—The cost of Phenol. Halogen Compounds: Tribromophenol — Iodophenols. Sulphonic Derivatives: "Sulphocarbolates"—Sozo-iodol—Aseptol—Sozal—Benzene-sulphonic Acid—Phenyl substituted Fatty Acids. Cresol and its Higher Homologues: Table of the Phenol Series—Sources—Creosote Oil—Uses of Creosote—Mixtures—Tricresol—Lysol—Experiments on its Efficiency—Pixol—Pixene—Solutol—Question of Solubility—Jeyes' Disinfectant and Creolin—Creolin Baths—Essets', Lawes' and other Fluids—Creocide—Ialine—Saprol: Its Peculiar Properties—Allen's Fluid—Production of Ozone. Izal: Europhene—Resorcinol—Pyrocatechol—Pyrogallol. Wood-Tar Derivatives: Products of Destructive Distillation of Wood—Stockholm Tar—Retinol—Resol—Fatal to Plants. Wood Creosote: Uses and Antiseptic Power. Guaiacol: Medicinal Uses—Guaiacol Carboxylate—Creosol—Kresyline—Little's Soluble Phenyle. Naphthalene and Naphthol: Naphthalene—Naphthalene-Sulphonic Acids—Naphthols—Beta-naphthol—Its Value in Internal Antisepsis—Betol: "Microcidine"—Alumnol—Hydronaphthol—Its Use in Gauze—Oxynaphthoic Acid.

Tar and its Products.

It has long been known that the varieties of tar have antiseptic and preservative properties; hence the use of coal tar for coating wood, and of wood tar for ropes and sacking. Coal tar consists for the most part of a mixture of "aromatic" compounds derived from the hydrocarbon benzene, C_6H_6. They are more or less volatile; many have offensive odours, and act as narcotic poisons. This poisonous action may render them disinfectant when used in sufficiently large quantities. Some coagulate albumen, and are caustic, like phenol. A few are soluble in water, and these have the most immediate physiological power. As far back as 1753 Bishop Berkeley extolled the virtues of tar water for nearly

every ailment; but its use is now replaced by more definite preparations.

By treatment with acid and alkaline solutions in succession, the tars are separated into three groups of bodies:—

I. Hydrocarbons, such as benzene, toluene, xylene, naphthalene, anthracene, etc. These are neutral bodies, insoluble in water, alkalies, and acids. Most of them, however, can be dissolved, or at least emulsified, by heating with a strong solution of ordinary or resin soap, with or without the addition of alcohol or wood spirit. The more or less clear brown syrup turns white and milky with water, the hydrocarbons being precipitated in minute oily globules, which slowly rise as a scum to the surface, leaving a strongly alkaline solution in the soaps. All these mixtures smell of tar, and are in different degrees antiseptic, but less so than the phenols. They are known in commerce as "neutral tar oils." Specifications for disinfecting powders generally demand their absence, and in fact they are looked upon usually as a detriment, or even as an adulteration, if present in any quantity in disinfectants. The hydrocarbon *benzene*, C_6H_6, and its higher homologues *toluene*, C_7H_8, etc., have no antiseptic value. The derivatives of thiophene (a compound usually present in crude benzene), C_4H_4S, have been used for skin diseases.[1]

Naphthalene, $C_{10}H_8$, and *anthracene*, $C_{14}H_{10}$, when pure, are white crystalline solids of greasy feel and tarry odour, slowly volatile, insoluble in water, and feebly antiseptic. Naphthalene is used as an insecticide, and is sometimes employed locally in scabies as a 10 to 20 per cent. solution in oil. It is to be avoided in cases where large surfaces are exposed, but has been used internally[2] and as an antiseptic for wounds.[3] Its derivatives will be further considered (p. 239). Naphthalene has been much used as the basis of cakes or blocks sold very cheaply as "disinfectants" to hang up over sinks and in closets, and to place in the basins of urinals. Some are said to contain "camphor and eucalyptus." The urinal blocks certainly prevent the urinous smell, partly by masking it and partly by retarding the ammoniacal

[1] *Répertoire de Pharm.*, 1892, p. 157.
[2] *Amer. Journ. of Pharm.*, 1884, p. 645.
[3] Squire's *Companion*, 1890, p. 289.

fermentation, but they are of no use as disinfectants. Naphthalene tablets have been patented.[1]

"Lauraline" contains camphor and carbolic acid with much naphthalene.[2]

Petroleum may here be incidentally mentioned, although it consists mainly of the paraffin series of hydrocarbons, such as hexane, C_6H_{14}. It has long been used as an insecticide in horticulture.[3]

II. Phenols, or so-called "tar acids," carbolic, cresylic, etc. They are hydroxy-derivatives of the aromatic hydrocarbons, and combine with caustic alkalies to form carbolates, etc., soluble in water, from which acids again liberate the phenol. The series includes phenol, cresol, and higher homologues; the latter are present in the fractions of higher boiling point, and form unstable compounds with alkalies which are even decomposed by water; hence their solutions turn milky on dilution. They are the basis of a large number of proprietary preparations, and will be described further under phenol, cresol, etc.

III. Basic substances are extracted from coal tar by treatment with acids; they contain nitrogen and are allied to ammonia. They are mostly soluble in water, and comprise pyridine and its homologues, with pyrrol, carbazol, quinoline, acridine, aniline, and other bases in small quantities. A further account will be given in Chapter IX.

Phenol or Carbolic Acid.

Phenol, $C_6H_5(OH)$, is the simplest member of the group of phenols or hydroxy-benzene derivatives, and is commercially known as carbolic acid. The phenols all contain hydroxyl united to the "aromatic" nucleus or benzene ring of carbon atoms, and are more or less antiseptic. Most of them coagulate albumen, and are therefore styptic; they are poisonous in different degrees, and thus, if in sufficient quantity may be true disinfectants. They are mostly of sparing solubility in water, but are readily dissolved by

[1] No. 5,036, 1892.

[2] *Chem. and Drug.*, Sept. 3, 1892.

[3] See a valuable paper by Lowe and Parrot, *Bull. New York Agric. Exp. Station*, No. 202, Dec., 1901; also *Journ. Soc. Chem. Ind.*, 1899, 852.

alkalies and alkaline earths (not carbonates), forming substitution compounds usually called carbolates. These compounds are alkaline, odorous, and somewhat caustic; acids, even carbonic, render their solutions turbid, separating the phenols as an oily layer if the solution is moderately concentrated. Such substances, made with lime or magnesia, constitute a number of the "disinfecting powders," which slowly give off the phenols on exposure to air, leaving behind the inert carbonates of lime and magnesia. The earthy bases then only act as a vehicle, and any undue excess of them must be considered as an adulteration. The pure compounds are not used, as they are deliquescent, caustic, and too rapidly soluble. The powders are usually valued and sold as containing a stated percentage of the phenol, etc. Many so-called disinfecting powders now in the market are supposed to contain 15 per cent. of phenol, when in reality they possess only a trace; moreover, even the best deteriorate on exposure to air, and may become inert, so that their activity should always be controlled by analysis. "A 15 per cent. carbolic acid disinfectant powder, free from tar oils and sulphuretted hydrogen" (*i.e.*, not made from gas-lime), is a common form of specification for this class of disinfectant. On the other hand disinfectant powders of undoubted efficiency exist which contain no true tar acids, and should therefore be included in any specification.

Phenol itself is prepared from tar distillates, and in the crude state is a dark oily liquid containing also the higher homologues, cresol, xylenol, cumenol, durenol, besides neutral tar oils of less disinfecting power. "Synthetic" carbolic acid, made from benzene and free from cresol, etc., has been sold, but its price is somewhat prohibitive. Pure phenol forms colourless crystals, with a tendency to turn red in the light. It melts at 41° C. and boils at 181·5° C., and therefore is not easily volatile. It can be volatilized more rapidly by melting and then dropping on to a heated shovel—not too hot, or it is liable to catch fire (*Calvert*). The vapour is apt to cause severe headache, giddiness, and nausea. Crystals of phenol are very hygroscopic and may contain up to 8 per cent. of water, a further quantity liquefies the crystals forming a hydrate, which, however, when added to still more water, only dissolves to the extent of 1 in 15, the

rest generally at first floating as an oily layer, although it is slightly heavier than water (specific gravity, 1·065). Hence it must be made into a solution for use by mixing with excess of water and agitating until dissolved. A clear solution, saturated in the cold, contains between 6 and 7 per cent.

It is certainly antiseptic; but as to its disinfecting power, opinions have been diverse. McDougall and Calvert extolled it above other disinfectants; but the latter observer, though he states that 1 in 200 prevented the putrefaction of beef juice for six days, yet acknowledges that when added in that proportion to already putrid beef juice or egg albumen, it had no effect on the organisms present. The vapour also produced no effect during twenty-four hours on vaccine lymph.

Miquel found that the vapour of phenol "after fifteen or twenty days of action at 20° C. is absolutely incapable of destroying the vitality of bacteria," and that 3·2 grammes of phenol are required to prevent growth in a litre of beef tea.[1]

Scheuerlen was the first to observe that the activity of an aqueous solution of phenol is very considerably increased by the addition of salts. Alcohol and caustic soda, however, when added to phenol diminish its activity.[2]

Pasteur and Lister strongly advocated its use in surgery where antiseptic action is mainly aimed at. Phenol was extensively tried by Crookes under the sanction of the Cattle Plague Commission. His report estimated its value in destroying the infectious matter as very high (1867).

Koch remarked[3] that "carbolic acid also kills, if of considerable strength and acting for a long period." He observed that solutions of carbolic acid in oil do not possess the same disinfecting power as those in water. This is important, in view of the frequent use of carbolized oil in surgery, and will be referred to later.

When disinfection is required to be completed in less than twenty-four hours, which is generally the case, Wolffhügel and Von Knorre found carbolic acid useless.[4]

In Koch's later experiments, silk threads with anthrax spores were placed in carbolic solution of various strengths.

[1] *Les Organismes*, 1883, p. 290.
[2] Paul, *Pharm. J.*, 1900, 339, 363.
[3] *Mittheil. a. d. K. Gesund.*, 1881, vol. i., p. 234.
[4] *Journ Soc. Chem. Ind.*, June 29, 1882.

A 5 per cent. solution killed the spores in two days, whilst sporeless bacteria, obtained from fresh blood, were killed by 1 per cent. solution, but not by ½ per cent. solution, as proved by inoculation. "As an antiseptic, phenol solution 1 in 850 entirely prevented the development of anthrax spores, 1 in 1,250 caused marked hindrance. Other bacteria are less affected. The vapour at ordinary temperatures, even when allowed to act for six weeks, had not the slightest effect on spores, but at 55° C. many were destroyed in half an hour. After three hours there was very little germinating power, after five or six all were killed. Other disinfectants act similarly at high temperatures."[1]

Klein observes that phenol (1 in 400 or 500) in nutrient solutions has a decided restraining power, but he emphasizes the fact that the spores are only "stunned," not killed; for, if removed and inoculated into an animal, they recover and rapidly cause death. He continues, "as is obvious, according to the nature of the bacillus, the strength of the solution, and the time of action, the result varies. For instance, mature B. anthracis is killed by 5 per cent. phenol in five minutes, but is not injured by 1 per cent. in five minutes." Other observers have found that resistant spores are not killed by 5 per cent. carbolic acid, and in the author's laboratory, anthrax spores have germinated in less than 24 hours' incubation, after four days' immersion in a 5 per cent. solution.

Crookshank obtained favourable results on the tubercle bacillus by inhalations of carbolic vapour.[2]

It is well known that certain organisms, especially those of the coli group and to a lesser degree *B. typhosus*, are capable of growth in the presence of small quantities of phenol[3]; culture material containing 1 in 2,000 carbolic acid is sometimes employed in bacteriology for the isolation of these organisms. Typhoid and coli are rapidly killed by carbolic acid exceeding 1 per cent.

Dr. Parkes[4] has recently pointed out that at the Children's Hospital, Chelsea, 1 in 80 carbolic acid solution employed

[1] *Mittheil. a. d. K. Gesund.*, Dec. 3, 1882. [2] *Bacteriology*, 1887, p. 151.

[3] Chantemesse and Widal, *Gaz. Hebdomadaire*, 1887, p. 146; also *Ann. Inst. Pasteur*, Oct. 25, 1890.

[4] *Public Health*, June, 1903.

for disinfecting the hands and utensils in the diphtheria wards, was found not to be efficient, and the strength had to be increased to 1 in 40.

The amounts of phenol that will hinder, or entirely prevent, alcoholic fermentation are given by Knoesel in a table[1] but a quantity sufficient to kill the yeast still leaves the inverting enzyme active.

The value of phenol may be summed up as follows:—

1. In a strength of 1 in 400 it is a powerful antiseptic, restraining putrefaction when started, and preventing it for a long time when not commenced, but in this respect it is far inferior to mercuric chloride.

2. To kill bacteria with any certainty, a greater strength than 1 per cent. must be employed. With spores, such as those of *B. anthracis*, phenol is useless, as they are apparently unaffected by a saturated solution.

3. It does not absorb sulphuretted hydrogen nor ammonias, hence it is not a deodorant.

4. Its persistent odour is a decided disadvantage, as the smell remains even when the quantity is utterly insufficient.

5. For treatment of sewage it is a failure, even in proportions practically impossible. Moreover, it renders the material useless for manurial purposes. In Japan, after a cholera outbreak in 1882, the Government instituted some experiments to elucidate this point, and clearly showed that "a solution of 0·05 gramme of phenol in 100 c.c. of water weakened the germinating power of the seeds, and with a solution of 0·1 per cent, only one-third of the possible seeds germinated, and in all cases the acid delayed the process of germination."

6. In surgery it is of considerable value. Lister has recently pointed out that it has a powerful affinity for the epidermis, penetrating deeply into its substance, and mingling with fatty matter in any proportion, whereas mercuric chloride required a special cleaning of the skin, as it could not penetrate in the slightest degree into anything greasy. Though it avoids the danger of mercurial poisoning, if used

[1] *Chem. Centr.*, 1902, xviii., 1065.

too strong it may itself be absorbed and cause dangerous symptoms. For aseptism (prevention) as against antiseptism (cure) in surgery it has, therefore, a distinct field of usefulness.

Carbolic acid is still in favour with different Governments and medical associations. Suggestions formerly made by the Society of Medical Officers of Health were as follows:—

1. For the air of sick rooms: sheets are suspended and saturated with carbolic solution or chloride of lime.

2. For matters passed: ferrous sulphate is added.

3. All utensils should be washed in carbolic solution.

4. Linen should be treated with the same.

5. Ambulances and steamers should be cleansed with carbolic solution.

The solution recommended was a $\frac{1}{4}$ pint of carbolic No. 4 (a pure liquefied acid containing about 90 per cent. phenol) to a gallon of water.

These recommendations were open to the criticism that:—

1. The prescribed solution, which only contains about $2\frac{1}{2}$ per cent. to 3 per cent. of phenol, is only half the strength specified by Koch and others as capable of killing mature germs, and far below that required to destroy spores.

2. The odour from a suspended sheet is liable, as before mentioned, to cause headache and nausea, and it is certain that such a method of application does little to disinfect the air, even if the carbolic solution is a saturated one.

The Commissioners of Inland Revenue in 1892 decided to adopt as standards a solution containing 80 per cent. of carbolic acid, and a powder containing 20 per cent.

Carbolic Powders.—In many cases the base of the powder consists of slaked lime, but the "carbolate" of lime, which is formed in this way, only slowly gives up its phenol. One of the oldest forms is "McDougall's Disinfecting Powder," prepared by adding crude carbolic acid to impure sulphite of lime obtained by passing sulphurous acid over ignited limestone. The sulphite of lime in this powder is added to absorb sulphuretted and phosphuretted hydrogen. It dissolves readily in water, so that there is no danger of choking drains. For fumigating purposes the powder is mixed with water in a wooden or earthenware receptacle, adding a little sulphuric acid.

Allen[1] gives the following as the composition of a sample of the base of McDougall's powder after extraction of the carbolic acid :—

Silica,	2·4
Alumina,	3·4
Ferric oxide,	Traces.
Lime,	46·5
Magnesia,	0·3
SO_2,	7·5
SO_3,	29·2
CO_2, water and undetermined matter,	10·7
	100·0

Corfield remarks : "Carbolates of lime and magnesia and sulphites, such as McDougall's powders, merely assist in delaying decomposition, but do not prevent it ultimately."

"Calvert's Carbolic Powder" is guaranteed to contain 15 per cent. of carbolic and cresylic acids. It is prepared by adding crude carbolic acid to the residue left from the manufacture of aluminium sulphate from shale or kaolin. The following is an analysis of the base after extraction of the phenol[2] :—

Silica	67·4
Alumina,	28·0
Ferric oxide,	Trace.
Lime,	0·8
Undetermined,	3·8
	100·0

The firm also manufacture a "concentrated carbolic powder" containing 50 per cent. of their refined No. 5 carbolic in a free state.

"Mayor's Disinfecting Powder" has also a silicate base "with 15 per cent. carbolic acid." "Phenolith" contains the phenols and cresols of tar with infusorial earth, sawdust,

[1] *Commercial Organic Analysis*, 1886, vol. xi.
[2] *Analyst*, 1878.

etc.[1]; the patent also includes the use of mixtures of phenol and boric acid for preserving meats, hides, etc. Tweedie[2] patented a mixture of phenol, turpentine, and camphor with "any dry vehicle." The carbolic powders of commerce are generally coloured pink or brown by aurin or ochre.[3]

The most suitable basis for disinfecting powders is made from a class of fossil deposits often incorrectly called "infusorial earths," but preferably termed *diatomites*, from their consisting largely of the silicious shields of diatoms. By calcining to get rid of water and organic matter, or sometimes by simply washing and drying, prepared "kieselguhr" is obtained as a light powder, containing 95 to 98 per cent. of silica. It has the following advantages:—

1. It is inert, and is unaffected by all reagents except fluorides, consequently it has been used for making bromine, and strong sulphuric acid, portable.

2. Volatility is much hindered through the active substance being enclosed by the hollow frustules of the diatoms, although a steady evolution is not prevented when the powder is freely exposed.

3. The product is so light as to float on water, hence any emanations have to pass through the disinfectant. One pound occupies the bulk of 3 or 4 lbs. of chalk.[4]

4. On the other hand it is easily penetrated by fluids, so that the added chemical readily dissolves or is diffused.

5. It is capable of absorbing a larger proportion of fluid than any known material that is available to the same extent. It can take up commonly 3 times its own weight and still remain a loose powder, which, however, can be compressed into blocks.

6. The reagent remains free and active, and none of it becomes combined or neutralized, as with chalk or lime.

It is now generally admitted that road disinfection by carbolized lime is of little value, since the volume of air and earth is too great for any real disinfection to be effected in this way. Local authorities, however, in many districts often regard such treatment with favour.

[1] Holtz, Patent No. 5,193, 1878.
[2] Patent No. 17,042, 1888.
[3] *Journ. Soc. Chem. Ind.*, 1889, p. 913.
[4] *Year Book of Pharmacy*, 1898, p. 340.

In surgery the following preparations containing phenol are used:—

Carbolized Solution, 1 or 2 of phenol in 40 of water; Carbolized Oil, same strength used as a dressing (much less power than the solution). Two per cent. solution for hypodermic injections and as spray for erysipelas[1]; 5 per cent. injection for anthrax.[2]

Carbolized Gauze (Lister).—Phenol, 1; resin, 4; paraffin, 4; melted together and the gauze dipped in this mixture. Vaseline is sometimes added to give pliancy.

Carbolic Wool should contain 5 per cent. phenol. Five commercial samples analysed were found to contain 1·06, 1·07, 0·69, 0·25, 5·08 per cent. respectively, showing that they were either badly prepared or had lost their strength by careless keeping. Carbolic wool, like all articles containing volatile medicaments, should be preserved in perfectly air-tight vessels.

Danger of Phenol in Surgery.—According to Lowe, the effect of the contact of phenol with any large surface of the lower part of the body is apt to be fatal, but it has often been applied to the arms with impunity. Gosselin made a series of experiments bearing mostly on the action of phenol on the living body, as in surgical operations, using 1 to 5 per cent. solutions in dilute alcohol upon blood circulating through a membrane, and found that the circulation of the blood through the capillaries was arrested, in direct proportion to the strength of the solution. He supposes that the phenol coagulates the blood like caustic, first (?) acting as a germicide, then "as a semi-caustic or astringent."

Carbolic Soaps are made in great variety. They should contain about 8 per cent. or more of phenol, but many contain not more than 1 per cent. Woodhead[3] and Cameron[4] have pronounced against their use. They are largely used in washing, and contain tar oils, naphthalene, etc., with varying amounts of phenol. Their value is more than doubtful as disinfectants, though they certainly are potent against insects.

[1] *Brit. Med. Journ.*, 1886, vol. xi., p. 947.

[2] *Ibid.*, p. 601.

[3] *Brit. Med. Assoc.*, Edinburgh Meeting, 1888.

[4] *Sanitary Record*, 1890.

Carbolic tooth powders are also made. They are antiseptic, but are not very pleasant.

A few other preparations remain to be mentioned. There are a large number of patents for mixing "phenoloids," containing more or less carbolic acid, with peat fibre, ground blast-furnace slag, cinders, sawdust, and other inert absorbents. They present no special advantage.

"Disinfectol" is an oily blackish liquid containing resinous soaps, soda, and compounds of phenol dissolved in hydrocarbons, introduced into commerce by Loewenstein. It mixes readily with water, forming an emulsion. Several preparations of this type, tar products dissolved in alkalies, will be described under *Cresol*.

"Rademann's patent" is pure phenol melted on a water bath, cooled quickly and stirred. The small crystals that separate are mixed with 10 per cent. of pure boric acid and pressed into cakes. He claims that this form is not injurious to the skin.[1]

An "Aromatic Carbolic Liquid," much used in Russia, is a tincture of phosphorized phenol with musk, oil of wintergreen, and other ingredients.

Phenol has been used internally in capsules and solutions to arrest fermentation, but opinions as to its value are conflicting. Betol has been found far preferable for this purpose (*q.v.*).

Vallin points out[2] that using 1 litre per day of a 5 per cent. solution of phenol for adding to excreta, etc., 50 grammes of phenol, or nearly 2 ounces, would be required daily for each patient. This would be a large item of expense in a hospital, and even in those devoted to infectious cases, the consumption of carbolic acid is seldom a fraction of this quantity.

Halogen Derivatives of Phenols.

The substitution in phenol of one or more of the hydrogen atoms by chlorine, bromine, or iodine can be easily effected by the action of these elements in the presence of water. Such substitution seems to increase the antiseptic power,

[1] *Journ. Soc. Chem. Ind.*, 1889, p. 131.
[2] *Désinfectants*, p. 385.

but at the same time it causes the compounds to become much more unpleasant in odour, diminishes their solubility, and makes them more corrosive and very irritating to the eyes.

Parachlorophenol, C_6H_4OHCl, is a crystalline body, m.p. 33° C., soluble in spirit, ether, and fixed oils, and practically insoluble in water. It has been used as an ointment (2 to 3 per cent. with vaseline) in the treatment of erysipelas and lupus.

A. Spengler also uses a 2 per cent. solution as an effective disinfectant for the sputa of phthisical patients.[1]

Hargreaves[2] manufactures "chlorophenols by the action of chlorine or hypochlorites on carbolic acid, tar, etc., mixed with absorbents to form a disinfectant."

Trichlorphenol, $C_6H_2Cl_3OH$, has been used in St. Petersburg as a disinfectant and claimed to be "25 times stronger than carbolic acid" (Martindale). It occurs in white needles of unpleasant odour and pungent taste, volatile with steam. It is nearly insoluble in water, but dissolves in dilute alkalies, and is again liberated by carbonic or other acids. The calcium and magnesium salts have been used medically and are not irritating.

Tribromophenol, $C_6H_2Br_3OH$, is a white or brownish crystalline volatile substance, very insoluble in water, obtained by adding bromine water to phenol solution, when it falls as a white precipitate. It is interesting as a delicate test for phenol, and as a way of separating it from cresol, since tribromocresol is liquid. Both compounds have disagreeable odours, and are antiseptic, but too insoluble to be of much use. "Xeroform" is tribromophenol-bismuth.[3]

Iodophenols are similar, but very unstable, being easily decomposed by light. Experiments with these compounds generally have not been favourable. "Traumatol," however, an iodocresol, was highly spoken of by Dr. Albert Robin from surgical experience in Paris hospitals.[4]

Sulphonic Derivatives.

Laplace found that treating with sulphuric acid rendered crude phenol much more soluble in water, and used the

[1] *Semaine Médicale*, Oct. 31, 1894.
[2] Patent No. 18,460, 1889.
[3] *Therap. Monats.*, 1899, xii., 64.
[4] *Repertoire*, vii., 14.

strongly acid liquid against cholera and typhoid. Concentrated sulphuric acid acts on the phenols, forming compounds soluble in water, and yielding soluble and crystallizable salts which are usually inodorous. In most cases two or more isomeric acids are formed, differing in characters; phenol itself gives the ortho- and para-acids. Their solubility, absence of odour, and the comparative harmlessness of the salts, have directed much attention to them as antiseptics. Their formation may be typified by the following equation—

$$C_6H_5OH + SO_2 \begin{matrix} OH \\ OH \end{matrix} = H_2O + SO_2 \begin{matrix} C_6H_4OH \\ OH \end{matrix}$$

The salts in commerce were formerly called sulphocarbolates, or phenyl-sulphates. The sodium and zinc salts are in the British Pharmacopœia. They easily crystallize and are inodorous.

Sodium Paraphenol-Sulphonate ("Sulphocarbolate") is a mild antiseptic, and is used in medicine for "disinfecting the intestinal tract." It is probably broken up in the body into phenol and acid sodium sulphate, each of which exerts an antiseptic action.

$$C_6H_5NaSO_4 + H_2O = C_6H_5.OH + NaHSO_4.$$

The Zinc Salt $Zn(C_6H_4O.HSO_3)_2$, has in addition the antiseptic and astringent properties of zinc. The calcium salt has also been used.

Vigier,[1] who has studied the relative antiseptic value of the three isomeric phenol-sulphonic acids, asserts that the ortho-acid is the most energetic.

The potassium-mercury salts of ortho-nitro-phenol para-sulphonic acids are described as soluble, very stable red-brown powders, without odour or taste, neutral, neither caustic nor irritant, not coagulating albumens, and not actively poisonous, and yet strongly bactericidal. They have been introduced under the name "Egols," being called "phenegol," "cresegol," etc., according to the phenol from which they are derived.[2]

Sozo-iodol, a sodium iodo-paraphenolsulphonate, is sparingly soluble in water, but easily in alcohol or in

[1] *Journ. Pharm.*, [5], vol. xi., pp. 145, 214.
[2] *Comptes rend.*, 1899, cxxix, 113. *Amer. Druggist*, June 10th, 1899.

glycerine. Its iodine is liberated by the action of light. It has been used locally in nasal and pharyngeal disorders, and in parasitic skin affections.[1]

Sozo-iodol-mercury contains 31·2 per cent. mercury and 38 per cent. iodine.[2] Draer has studied the action of both these compounds on the cholera bacillus.[3]

Aseptol is an ill-defined mixture of phenyl ethers and sulphonated phenols prepared by the action of sulphuric acid on phenol in the presence of alcohol.[4]

Sozal, aluminium para-phenolsulphonate $(C_6H_4OHSO_3)_6Al_2$, occurs in small crystals, having a slight odour of phenol, readily soluble in water, glycerine, and spirit, and useful in surgery as an astringent and bactericide (Girard and Lüscher).

Hueppe describes a sulphonic derivative of phenol-ortho-phenyl sulphonic acid, which is less caustic and more antiseptic than the parent substance.[5] Kaemar[6] covers the use of certain sulphonates as disinfectants.

Benzene-Sulphonic Acid, $SO_2(OH)C_6H_5$, an acid liquid obtained by adding benzene cautiously to sulphuric acid with 30 per cent. of sulphuric anhydride, was patented by Giles and Shearer[7] as an antiseptic, disinfectant, and deodorizer. It is a question whether it would be superior to sulphuric acid alone.

Sulphonating as a rule reduces the poisonous action of both the hydrocarbons and the phenols, without destroying their disinfecting properties. Further comparative experiments with known organisms with the same weight of compound with and without a "sulphonic group" would be of value. The sulphonates of hydrocarbons containing more than one closed chain should be especially active. It is claimed that sulphonic derivatives of tar hydro-carbons (particularly the salts of phenanthrene-mono- and di-sulphonic acids), and also of carbazol, act as real solvents for cresol.[8]

[1] *Brit. Med. Journ.*, 1889, vol. xi., p. 42.
[2] *Pharm. Journ.*, 1889, p. 577.
[3] *Am. Journ. Med. Sci.*, March, 1894.
[4] Serrant, *Jahresbericht f. Thierchemie*, 1885, p. 499.
[5] *Brit. Med. Journ.*, 1891, p. 1107; also on the Sulphocarbolates see *Journ. Soc. Chem. Ind.*, 1889, p. 912.
[6] Patent No. 3933, 1892.
[7] Patent No. 14,864, 1887.
[8] Patent 7719 of 1901.

Such solutions, if produced economically, would be of special value as disinfectants or for pickling timber.

Phenyl-substituted Fatty Acids.—Klein[1] showed that the phenyl-propionic acid has a more powerful antiseptic action on anthrax bacilli than phenyl-acetic acid. J. Parry Laws[2] has further shown that phenyl-butyric acid restrains the growth of anthrax bacilli when present in the proportion of 1 in 2,500, and that it kills the sporeless bacilli when they are exposed for thirty minutes to a solution of 1 in 1,000, or for ten minutes to a solution of 1 in 700.

The following table shows the relative value:—

	Phenol.	Phenyl-Acetic Acid.	Phenyl-Propionic Acid.	Phenyl-Butyric Acid.
Restraining Power, .	1 in 700	not determined	1 in 1900	1 in 2500
Killing Power, . .	1 in 200	1 in 450	1 in 600	1 in 1000
Length of Exposure .	45 mins.	30 mins.	30 mins.	30 mins.

Thus they increase in antiseptic power with increase of molecular weight. Duggan[3] has shown that the converse is true in the case of the fatty acids when tested on *B. subtilis*. His results give as the strengths necessary for killing:—

Formic Acid.	Acetic Acid.	Propionic Acid.
7 per cent.	9 per cent.	12 per cent.

These percentages almost exactly correspond to their relative molecular weights, and consequently to their relative saturating power of bases.

Cresol or Cresylic Acid and the Higher Phenols.

The higher phenols may be regarded as derivatives of phenol in which one or more of the hydrogen atoms of the "benzene ring" have been replaced by methyl or other fatty radicles. These substitution products form a homologous series of progressively increasing density and boiling

[1] *Thirteenth Annual Report Local Government Board.*
[2] *Chem. News*, 1895, p. 15.
[3] *Am. Chem. Journ.*, vol. vii., p. 62.

point, and diminishing solubility, of which the following are examples:—

Table of the Phenol Series.

Systematic Name.	Commercial Name.	Empirical Formula.	Rational Formula.
Phenol, . . .	Carbolic Acid	C_6H_6O	$C_6H_5 . OH$
Methyl-Phenol, .	Cresol or Cresylic Acid	C_7H_8O	$C_6H_4(CH_3) . OH$
Dimethyl-Phenol, .	Xylenol	$C_8H_{10}O$	$C_6H_3(CH_3)_2 . OH$
Trimethyl-Phenol, .	Cumenol	$C_9H_{12}O$	$C_6H_2(CH_3)_3 . OH$
Tetramethyl-Phenol .	Durenol	$C_{10}H_{14}O$	$C_6H(CH_3)_4 . OH$

Of all, except the first, several isomerides are known. They are all antiseptic; their relative values is not exactly known, but the cresols are decidedly higher than phenol. All dissolve in strong alkalies, giving soapy antiseptic solutions: these compounds in the higher members of the series are decomposed by water, yielding milky emulsions which slowly deposit the oil. The homologues are less poisonous than phenol, and are classed together as phenoloids.

A mixture of these bodies from which phenol had been separated, formerly constituted a waste product of the carbolic acid manufacture under the name of "creosote oils," and was used for preserving timber, etc. They are difficult to separate by fractional distillation, and now in various mixtures they are largely used for disinfectants under a great number of fancy names. Some of them contain also the hydrocarbons, or neutral tar oils, and a few contain also the bases. The complicated nature of many of these patents is partly due to the effort to increase the solubility or diffusibility of the phenoloids. F. W. Alexander[1] points out that if they have not been properly purified from hydrocarbons such as naphthalene, they will be liable to "salting," or a crystallization which hinders the liquid from pouring, and that when ordering this class of fluids it is necessary to add the words "guaranteed commercially or practically free from salting."

The waste gases from blast furnaces, formed by the destructive distillation of the upper layers of coal and bituminous iron ore, when cooled, deposit large quantities of

[1] *Lancet*, Jan. 20th, 1900, p. 158.

empyreumatic products, from which is manufactured on a large scale, in Scotland, the mixture called "blast-furnace creosote oil" for creosoting timber. It contains 20 to 35 per cent. of phenoloid bodies soluble in caustic soda, the coal-tar creosote oil made in London only containing 5 to 10 per cent. Watson Smith found one sample of the phenoloids obtained from blast-furnace tar to contain only 1·33 per cent. of phenol having a boiling point of 182° C., while those obtained from Lancashire tar contained 65 per cent. of crystallizable carbolic acid (the phenol may have been previously separated from the former). The fraction that would contain cresol had 4·5 per cent. of phenoloids, and the fraction boiling from 210° to 230° consisted of a mixture of the xylenols and cresols. The "creosote oil" is treated with caustic soda, the insoluble hydrocarbon oils separated, and the soda compound decomposed by the waste gases from the furnace. Sodium carbonate is formed, setting free the phenoloids. The carbonate of soda is treated with lime, giving fresh caustic soda for another quantity of oil. The crude phenoloids are distilled, yielding the "creosote" of commerce. It contains about 1 to 2 per cent. of phenol, a large quantity of cresols, and a smaller quantity of the higher homologues. The oxyphenols, similar to those found in wood creosote, are present only in very small quantities.

Schulze[1] has found in coal-tar cresols 40 per cent. meta-cresol, 35 per cent. ortho-cresol, and 25 per cent. para-cresol.

When fresh, creosote is almost as colourless as water, but it gradually darkens on keeping, slowly forming tarry products of less potency. In most forms it is a stronger antiseptic than crude carbolic acid, and has not such a caustic action on the skin.

Buchholtz states that the least quantity of creosote that would prevent bacteria from developing in Pasteur's fluid was 1 in 2,000.

Creosote has a strong power in checking fermentations, hence its name (κρεας, flesh; σωζω, I keep). Although only slightly soluble in water, its solution has preservative powers. It has been used for preserving organic putrescible liquids, and for keeping provisions, but its taste and odour

[1] *Ber. cl. Chem. Gesells.*, vol. xx., p. 410.

are more unpleasant than those of the "creosote" from wood tar. It is administered internally to check fermentation in the stomach, but is a dangerous and unpleasant remedy, as it suspends digestion. Inhalations of coal-tar creosote vapour have no effect on phthisis, but are useful for cases of fœtid expectorations arising from bronchiectasis (*Chaplin*).

With reference to the antiseptic power of these creosotes, it has been shown that mixtures have often more energy than any of the ingredients used singly. This may be due to the fact that different species of organisms have quite distinct susceptibility to different agents. Lacroix Hunkiabeyendian observed that a mixture of ortho-, meta-, and para-cresol exerts a stronger action upon *Staphylococcus pyogenes aureus, Tetragonus prodigiosus,* and the bacilli of cholera and typhoid than any of the pure compounds used singly.[1]

Tricresol, introduced by Schering, of Berlin, is a purified mixture of the three cresols in the proportions found in coal tar, and is less toxic than phenol. It is synthetically prepared from toluene, $C_6H_5(CH_3)$. According to Professor Gruber, water dissolves from 2·2 to 2·5 per cent. of tricresol; but a 1 per cent. solution only is required in surgery, "that being equal in antiseptic power to a 3 per cent. carbolic acid solution."[2] Tricresol is at first perfectly colourless, has the odour of creosote, and boils from 183° to 205° C., the fractions being—

	Below	183°	=	...	per cent.
183°	,,	185°	=	4·3	,,
185°	,,	190°	=	5·3	,,
190°	,,	195°	=	56·0	,,
195°	,,	202°	=	34·4	,,
				100·0	

"As phenol boils at 183°, and the cresols between this temperature and 202°, it follows that phenol, xylenol, and the other members of this series are practically absent. The specific gravities of the fractions are 1·042 to 1·049 at 20° C. It is stated to contain 40 per cent. of meta-, 35 per cent. of

[1] *J. de Pharm. et de Chimie*, 1892.

[2] *Pharm. Zeitung*, 1894, No. 4; 1895, No. 97; *Archiv. f. Hygiene*, vol. xvii., p. 618.

ortho-, and 25 per cent. of para-cresol." The following table gives the physical properties of these three compounds:

	Boiling Point.	Melting Point.	Spec. Gravity.	
Orthocresol, . .	191°	30°	1.0053	Crystalline.
Metacresol, . .	203°	4°	1.05	Liquid.
Paracresol, . .	202°	36°	.996	Prisms.

Tricresol does not attack instruments, nor make the hands numb and slippery, like carbolic acid and soap preparations (Helbing).

Lysol is prepared by Schulke and Mayr, of Hamburg,[1] by dissolving in fat and subsequently saponifying, with the addition of alcohol, the fraction of tar oil which boils between 190° and 200° C. (practically the cresols, excluding almost all the less soluble xylenols, etc.). It is a brown clear syrup containing about 51 per cent. of higher phenols, but no carbolic acid. It is miscible with water to a clear saponaceous, frothing fluid. The ash is about 6 per cent., and is mainly carbonate of potash. Lysol shows turbidity when mixed with hard water from the formation of the well-known precipitate of lime and magnesia soaps, but its disinfectant quality is not impaired thereby. It forms a clear solution with alcohol or glycerine. Dr. Schottelius[2] gives the minimum effective strength of the following in per cents.:—

	Lysol	Creolin.	Phenol.
Staphylococcus pyogenes aureus, . . .	0.3	1.2	2.5
Bacillus typhosus	1.2	...	...

"Pearson's creolin was used." Lysol of ·33 per cent. destroyed in twenty minutes cholera and typhoid bacilli.[3]

It removes all dirt, fatty and resinous spots from the

[1] English patent, No. 1,017, 1890.

[2] *Münchener Med. Wochenschr.*, 1890, No. 20.

[3] Engler, *Dingl. pol. J.*, vol. cclxxviii., pp. 26 to 78; *Journ. Soc. Chem. Ind.*, 1890, p. 1,136.

skin, as well as from linen, instruments, and the like.[1] To remove the soapy feeling, the hands may be rinsed in sterilized water and dried with a sterilized towel.

Gerlach and Simmonds tried it on infected fæces with success. Cramer and others recommended it in surgery. E. P. Miles reports his own experience as follows[2]: Lysol 2 per cent. prevented the growth of micro-organisms and decreased the amount of suppuration when washing a wound on a horse: Creolin 1 per cent. retarded the growth of pus-producing organisms, but did not destroy them in 15 minutes: Dermatol, indol, aristol, zinc oxide and mercuric chloride were found unsuitable: Mercuric chloride 1 in 1000 retarded the growth of organisms, but was not strong enough to be of use, while stronger solutions are injurious to the tissues.

Hautefeuille[3] finds that 0·5 to 2 per cent. is fatal in a few minutes to most pathogenic organisms when freely exposed, and that a 2 per cent. spray destroyed B. typhosus, coli, diphtheria, as well as staphylococci and streptococci, on paper slips. As usual, when embedded in pus or membrane a longer contact was necessary. Tuberculous sputum was sterilized when mixed with a 2 per cent. solution in 24 hours, and with a 4 per cent. solution in 12 hours. Lysol is generally agreed to be $2\frac{1}{2}$ times as effective as pure phenol. It appears to be an efficient preparation for surgical purposes, but the mode of its manufacture would seem to make it too expensive for use in large quantities for public disinfection.

Cramer (*Centralb. für Gynäkol.*, October 1st, 1898) reports a case of fatal poisoning from the use of three pints of one-per-cent. solution of lysol as a uterine douche. Several cases of death following the ingestion of pure lysol have been reported, while in three instances its application upon skin wounds has resulted fatally; but, so far as known, this is the first fatal case from the use of a diluted solution of lysol. The uterine injection was made immediately after the birth of the placenta, but was suddenly interrupted by the collapse of the patient. She recovered from the collapse,

[1] *Arch. d. Pharm.*, ccxxx., 562; cxxxii., 351.
[2] *Virginia State Bulletin*, 1892, No. 18.
[3] *Rev. d' Hygiène*, 1903, xxv., 167.

however, only to die ten days later with symptoms similar to those of carbolic acid poisoning. Cramer reckoned that a quantity of lysol equal to seven minims of the drug may have found entrance to the venous circulation. The value of uterine injections depends not so much upon the disinfecting power of the fluid used as it does upon the mechanical cleansing. Hence the importance of having the antiseptic fluid as weak as possible, in case irrigation is employed after child-birth. Indeed, for this purpose, many prefer normal salt solution to any disinfectant.[1]

"Lysolveol" is described as a strong aqueous solution of phenols, cresols, resinous and fatty potash soaps (chiefly oleate), with a small proportion of hydrocarbon oils. It has a sp. gr. of 1·022.[2]

Pixol (*Eberman and Raptschewski*) is made by slowly adding a mixture of 3 parts of wood or coal tar and 1 part of "green potash soap," heating, if necessary, to 3 parts of a 10 per cent. solution of caustic soda. A clear brown liquid, miscible with water, results. "A 5 per cent. solution has the same power as lysol of the same strength, and is cheaper." The *Lancet*, October 14th, 1893, states that this disinfectant was found useless in the cholera wards of the Obrickooski hospital at St. Petersburg, as the solution of tar did not kill cholera bacilli, and had only a slight inhibitory power on their growth.

"Pixene" is a preparation of the same class, made by Wheeler from light tar oils. It mixes readily with water.

The Lysol class of preparations, giving clear solutions with water, owe this property to the special method of saponifying, using potash with alcohol, glycerine, or other reagents, or to their freedom from neutral tar oils, with a consequent addition to their cost. Von Heyden showed that the higher phenols are rendered soluble by mixing with sodium salts of acids like benzoic, salicylic, etc.,[3] and we have already mentioned the use of sulphonic acids (p. 212). Von Heyden's "Solutol," however, is a brown liquid containing chiefly sodium cresolate. A sample examined by the author in 1897 showed ash 18·25, soda 11·65, tar acids

[1] *Med. World*, Jan. 21st, 1899.
[2] *Zeits. oest. Apoth. Ver.*, xxxv., 754, 795.
[3] Patent No. 9103, 1890.

62 per cent., and no neutral oil could be separated. Cultures of B. coli communis gave with equal strengths (1 : 200) of three disinfectants the following results: Solutol, sterile after 1 to 2 hours; Jeyes' Fluid, after $\frac{1}{4}$ to $\frac{1}{2}$ hour; Izal, in less than $\frac{1}{4}$ hour. This would show a distinctly greater energy in the emulsions. Other observers have stated that a one per cent. solution of Solutol is almost immediately fatal to Staph. pyog. aureus, and that 10 per cent. rapidly destroys anthrax spores.[1] "Solveol" is a solution of cresol in cresolate of sodium. According to the *British Medical Journal*, 1891, p. 414, a mixture of soluble tar products with sodium salicylate and water under the name of "resole" made a solution which was very effective (see p. 235). Engler and Dieckhoff have made an exhaustive examination of those cresol preparations which are soluble in water.[2]

The real question at issue is—Should a disinfectant be easily soluble in water or not? On the one hand, it would at first sight appear that to penetrate through the envelopes of bacteria requires an agent *which is in solution*, and therefore diffusible. But Mr. Worrall in the introduction of "Izal," took exception to such a conclusion, and claimed that "insolubility in water is one of the most valuable properties of this preparation, since when once applied to a part requiring disinfection it is not easily washed away, and therefore fulfils its purpose more effectively." In some emulsions, such as the one mentioned, the active material is in a finer state of division than the food in the duodenum, which we know is readily absorbed by the intestine, and therefore such emulsions probably penetrate bacteria in a similar way, while the fact that emulsions do kill is a proof that solution is not essential.

There is no doubt that emulsions of tar oils have several sources of popularity with the public; they look strong, their odour enables their presence to be felt, and their appearance enables one to judge when they are properly mixed, instead of falling to the bottom of the liquid, like solid disinfectants, or floating on the top and being carried away, like phenol. Moreover, the minute oily globules in

[1] *Chem. and Drug.*, June 19th, 1897, but see Paul's statement, p. 225.
[2] *Archiv. der. Pharm.*, No. 232, pp. 351-365.

these emulsions do slowly dissolve, and exercise a strong inhibitory action on the germs for long periods of time, so that the sewage may be carried away before it has a chance of conveying infection.

The best of these preparations may be regarded as strongly antiseptic and useful against infection, though it must always be remembered that, as Klein has pointed out in anthrax, Karlinski in excreta of typhoid, and Kitasato in cholera stools, the matter apparently disinfected, in which no growth may appear for days, if it be removed to fresh sterilized excreta (*Kitasato*), or inoculated into the blood of fresh subjects (*Koch, Klein, Blyth,* etc.), will often begin to grow and prove fatal, the organisms having been stupefied and not killed.

Here the emulsified and slowly dissolving oil might have a distinct advantage, as, so long as sufficient of it remained, the spores would be prevented from growing.

Among the more important emulsions containing cresols is—

Jeyes' Fluid.—In the first patent[1] "resin and creosote or naphthalene are heated with soda." Patent No. 5,249, 1877, proposes "coal-tar distillates above a 1,000 specific gravity" (this would include phenol and a large number of other bodies) "to be mixed with resin, soda, and vegetable oils" (giving a resin soap and a fat soap) "so as to make a milky emulsion with water." An anthracene salt (?) or naphthalene also may be added. This very complex mixture seems to have been the original form of "Jeyes' disinfectant," a dark brown, syrupy liquid which gave a brownish-white milk easily diffused through water, a large proportion of the oils, etc., remaining quite insoluble. It then had an unpleasant smell and left dark tarry stains on flooring, but it has since been greatly improved, containing more of the cresols, and only a trace of naphthalene.

Three samples of this fluid examined by the author in 1895-96 gave the following percentages:—

	I.	II.	II.
Ash	2·85	2·89	3·12
Alkali as NaOH	1·7	2·06	2·11
Water	6·0	6·0	8·0
Tar Acids (by volume) ...	22·5	23·0	22·2

[1] No. 4636, 1877.

Another application[1] melts together resin, naphthalene, and pitch, mixes with soda or potash, and makes into cakes, which are broken up and dissolved in water when wanted. Unless there were a great proportion of alkali, the "solution" in water would be very slow, and would require a great deal of stirring.

It may be here mentioned that potash, the basis of lysol, saponifies more rapidly than soda, and the product, being a soft soap, is more soluble than the hard soap made with soda. The mixture of the two alkalies is therefore advantageous.

For drains, etc., the fluid is directed to be mixed with 50 parts of water. It is also recommended as a spray, and for fumigation here it would have the same limitations as other products of slight volatility.

Jeyes' Fluid is free from phenol, but since it contains "more than 3 per cent. of the homologues of carbolic acid," namely the cresols, this fluid, in common with other disinfectants of the kind, must be labelled "poison" and "not to be taken internally," according to the Privy Council Order of June 5th, 1902. That this preparation is much less poisonous than phenol, is proved by an instance in London where a woman took 4 ozs. of Jeyes' fluid with the object of committing suicide, but was not injured. The *British Medical Journal*, January 11th, 1890, also cites a case in which a man took nearly 9 ozs. with the same object. "He soon became unconscious, but was discharged, cured, in the third week after admission." Such a result would have been impossible with carbolic acid.[2]

Jeyes' Creolin was formerly the name of a more refined preparation by the same makers, of cresols and neutral tar oils in emulsion, without phenol. It was a brownish-black alkaline syrupy liquid of empyreumatic odour, giving a soapy emulsion with water.[3]

The bacteriological reports on these two fluids are very favourable. Dr. Von Esmarch in Koch's laboratory at Berlin found that "1 per mille killed the cholera bacillus in ten minutes, whereas carbolic acid took four days." Dr. Eisenberg, of Vienna, states that 6 per cent. of it killed even anthrax spores in twenty-four hours, while phenol did not

[1] Patent No. 2,669, 1882.

[2] See *ibid.*, 1891, p. 49, for a confirmatory case.

[3] See *Lancet*, Jan 5th, 1889.

destroy them in a week. "Spores of the hay bacillus (*subtilis*) which possess the greatest power of resistance, were killed by 6 per cent. of creolin in six days; phenol failed."

Dr. Washbourn[1] repeated the experiments of the two previous observers with confirmatory results. He concludes that "creolin is a good antiseptic, certainly superior to carbolic acid in its action on sporeless bacteria, and probably superior also when acting on spores." He finds that 5 per cent. creolin is equal to 1 per cent. of mercuric chloride.

Creolin and Jeyes' fluid have found great favour in hospitals for warm baths in infectious and skin diseases. Their results are certainly very good. But for sewage, or for fumigation, "disinfection" cannot be maintained, as it is proved by experiments that 5 per cent. is required to destroy all pathogenic organisms, and the cost of this would be almost prohibitive.

In addition to "Jeyes' Fluid" the company now supply an improved "Creolin Medical" and "Creolin Disinfectant." Formerly, as already mentioned, under the name creolin, a preparation containing 18-20 per cent. of cresylic acid was sold in this country, but it was inferior to the new article now known under that name, which is said to be free from phenol and its homologues. Owing to the confusion of names it is always advisable to obtain a "carbolic acid co-efficient" for any preparation, and stated generally it may be taken that these fluids should be equal to at least fifteen and ten times respectively their weight of pure carbolic acid, when tested on B. typhosus.

Lano-creolin, soaps, gauze, etc., are also made, and capsules containing 3 minims each.

Cyllin is identical with Creolin Disinfectant (Jeyes).

Essets Fluid is an alkaline solution of higher phenols similar to Jeyes' fluid, giving, like it, a milky emulsion with water. The *Lancet*, July 1st, 1893, pronounces it "an efficient disinfectant and antiseptic." It may be mentioned that the strength of solution recommended to be used for closets, drains, etc., viz., one teaspoonful to a gallon of water, or 1 in 320, is much too dilute to be efficient.

The following are among the numerous similar preparations which have appeared. A number of them have been

[1] *Guy's Hospital Reports*, vol. xlv., 1888.

examined in the Author's laboratory, and some of the results are appended, but it must be remembered that the composition is in many cases far from constant, a feature that calls for standardization (Chap. XVI).

Lawes' Fluid and Powder. In the former I found, in 1895, per cents., water 6, light oil 2·5, heavy oils 73·4, including tar acids 19, and much hydrocarbon oil. Sp. gr. 1·016. Tested in 1 per cent. strength with Staph. pyog. aureus, B. coli, and Sp. choleræ it showed decided superiority over pure carbolic acid at the same dilution. Another sample analysed subsequently by the *Lancet*,[1] was reported to contain over 25 per cent. of true phenols and no inert tar oils, and it was added that the disinfecting powder contained at least 16 per cent. of active phenols.

"Odamine," "Germol," and "Vitos" fluids resemble the above, and gave almost identical bacterial results in 1 per cent. solutions in my own experiments.

"Creocide" (Sanitas Co.) in its new form is an improvement on the older preparation of the same name, which I examined in 1895 and then found satisfactory. In my bacterial tests of the new form in 1901, it compared very favourably with carbolic acid as regards B. coli, two different stocks of B. typhosus, and Staph. pyogenes aureus, while B. diphtheriæ was destroyed by $\frac{1}{4}$ per cent. of the new creocide in less than half the time required by the $\frac{1}{2}$ per cent. solution of carbolic acid.

"Ialine" (Burt, Bolton and Heywood) is stated to contain: "A" fluid 25 per cent., and "B" Fluid 23 per cent. of tar acids, "besides other antiseptic properties."

"Pearson's Antiseptic" according to an analysis by W. J. Dibdin in May, 1903, contains in per cents.: Light oils 9·1, tar acids (cresylic fraction distilling between 180° and 210° C.) 21·9, hydrocarbons 32·6, distillate above 250° and residue 36·4: sp. gr. 1·0475. The purified ortho-, meta- and para-cresols amounted to 17·7 per cent. The phenoloids were practically free from carbolic acid. "The disinfecting power was superior to carbolic acid in such ratio that about 25 per cent. more of the latter was required to exert the same antiseptic power." Klein's report in June,

[1] *Lancet*, June 29th, 1895.

1903, states that B. coli communis was killed by the 1 per cent. emulsion in 2½ minutes, and Staph. pyog. aureus by the 3 per cent. emulsion in 1 minute, but not by the 1 and 2 per cent. in 5 minutes.

"Quibell's Disinfectant" is of a similar character and we understand has been lately improved. A test with B. typhosus in the author's laboratory in 1903 showed that a 1:200 dilution killed the organism in between 7 and 17 minutes, and a 1:100 in under 7 minutes.

According to Paul[1]: Solutol, Solveol, Lysol and Creolin are incapable of destroying the spores of B. anthracis even when used in the concentrated state.

A saponified cresol is included in the new German pharmacopœia. It is made from red cresol and soft soap.

Saprol (Nördlinger of Bockenheim, Frankfort), is a dark brown oily liquid smelling like crude phenol, having a mean specific gravity of 0·990. Dr. Spindler, of Stuttgart, finds that it contains phenol and cresol, 43·0; hydrocarbons, 53·9; pyridine and other bases 2·8 = 99·7.

When poured into water a separation occurs, the heavier cresols partially dissolving and partially sinking in drops, while an oily scum of the hydrocarbons floats on the liquid. This covering, according to Professor Quincke, of Heidelberg, amounts to 0·2 milligramme per square millimetre. Scheurlen[2] finds that when saprol is thus poured upon water, and left to stand for three or four days, from 33 to 39 per cent. of it—that is, the greater part of the cresol and phenol dissolves. The liquid contained 0·41 to 0·49 per cent. of cresols. He proved that either crude phenol or saprol itself, even if shaken repeatedly for seven days with water, only yielded solutions of 0·45 to 0·51 per cent. of cresols, so that he concludes that 0·5 per cent. is the mean solubility of the cresols, and that the latter, if time be allowed, dissolve just as well when merely poured on water, as when continuously and vigorously stirred. "This fact, applied to the disinfection of fæcal matters, proves that by the use of saprol a mixture of the fæces supersaturated with the disinfectant is obtained." Dr. H. Gross found that the addition of dilute alkalies or

[1] *Pharm. Journ.*, 1900, 339-343.
[2] *Archiv. f. Hyg.*, 1893.

acids did not increase the solubility (?). It is also pointed out that while the uniform coating of saprol entirely prevents contact with the atmosphere, so that no evil-smelling gases can be emitted from the fæces, the usual oxidation process is also checked, while the soluble parts of the saprol gradually penetrate right through the mass.

According to Laser,[1] a thin layer of saprol kept urine clear, without smell and sterile, for twenty-two days. A thick layer sterilized anthrax cultures in twenty-four hours. Urine, which had been standing under a thin film of saprol for twenty-three days, was filtered and mixed in three glasses with (1) cholera vibrios, (2) typhoid bacilli, and (3) *Staphylococcus pyog. aureus*. In all three glasses the micro-organisms were killed. He also made a series of researches with increasing quantities, to ascertain the amount required to disinfect and deodorize urine, and, as a result of his experiments, concluded "that 1 per cent. of saprol is sufficient for the disinfection of fæces and urine."

Scheurlen[2] confirms these results. It must be remembered that a 1 per cent. solution of saprol is equivalent to about 0·43 per cent. solution of the cresols.

The special claim of saprol is its peculiar physical action —viz., "being a little lighter than water, partially soluble and partly insoluble"—by which it—

1. Forms a complete coating over the substances, so keeping them from the atmosphere, and masking smells.

2. Diffuses gradually and evenly through the putrescent matters, first restraining and then killing the organisms.

3. Acts in less strength (1 per cent.) than phenol (2½ per cent.).

As to cost, it is stated that "1 litre per month, costing 60 *pfennige* (about sevenpence halfpenny), is sufficient for a household of 20 people, or 3 *pfennige* (less than a halfpenny) per month per head."

It must be admitted this is a very strong case for saprol. It and lysol are much used in Germany, the former for common, and the latter for surgical purposes. It is to be noted that natural oxidation is retarded by saprol; unless the

[1] *Centr. f. Bakteriologie*, 1892, vol. xii., p. 78.
[2] *Arch. f. Hyg.*, 1893.

excreta be removed quickly they will be liable to grow organisms again, as even with such cheapness it would be difficult and expensive to attain a sufficient strength for sterilization. A similar reservation applies to all this class; they are really more antiseptics than true disinfectants, and their action as deodorants is simply that of a mask.

The presence of pyridine (which is very soluble) must not be forgotten. Neither sulphuretted hydrogen nor ammonias would be effectively absorbed; hence it would be advisable to use one of the chemical absorbents as well.

The flashing point of saprol is 90° to 100° C., about the same as that of phenol, and sufficiently high for safety under ordinary circumstances. Unless heated, a light applied to it does not cause it to inflame.

With some of these preparations containing the higher phenols, ozone is stated to be produced when they are exposed to the air. This action is claimed in Allen's "hygiene disinfecting fluid," but this fluid is recommended to be used at a strength of 1 in 500, whereas all experiments go to prove that 1 per cent. is the lowest effective dilution for any tar preparations. As to the production of ozone, Dumas[1] endeavoured to explain the slight deodorant properties of the tars in the light of the experiments of Schönbein on the abundant formation of ozone in air mixed with the vapours of essence of turpentine, but the later experiments have shown that in all probability more hydrogen peroxide than ozone is produced by the phenols in the presence of air and moisture.

Izal.—In the process of carbonizing coke in close ovens, an oil condenses which contains, besides higher phenols, some peculiar compounds different from those in coal tar. From it J. H. Worrall obtained at the Thorncliffe Ironworks, Sheffield, a clear, deep reddish-brown liquid insoluble in, and of greater density than, water. Analysis showed that it was not a homologue of the coal tar phenols, as it contained more hydrogen and had the group-formula $C_nH_{2n-4}O$. Its vapour density corresponds to the empirical formula $C_8H_{12}O$. The mean boiling point—*i.e.*, it is a mixture—"is considerably higher than that of carbolic acid (183° C.), and it has

[1] *Acad. des Sciences*, July 25th, 1859.

not the caustic action on the skin as has that antiseptic; moreover, it is non-poisonous to the higher animal life." This insolubility and high boiling point "insures the antiseptic body remaining upon the part requiring disinfecting after it has once been there deposited." When suspended in water, forming a milk-white emulsion, it is easily distributed by water. "It remains liquid at all temperatures above 32° F., while a temperature of 212° F., instead of deteriorating, only tends to concentrate it. The emulsion mixes readily and perfectly with water in all proportions." It was originally called the "Thorncliffe disinfectant," but is now known under the name of "izal."

Mr. Worrall tried izal on the *Acarus* of the sheep, and found one treatment to effect complete cure, "proving that not only were the parents destroyed, but the antiseptic body remained to destroy also any insects hatched from the eggs which the parents had deposited previous to their death" ("the time of egg-incubation and larva-development is ordinarily fifteen days"). This seems to be a far more legitimate inference than that the eggs themselves had been destroyed.

Klein,[1] reported that izal had "a quite remarkable bactericidal effect. An exposure for five minutes to izal in the strength of 1 in 200 completely destroys the vitality of the microbes of diphtheria, typhoid, fowl-cholera, swine fever, glanders, cholera, suppuration, erysipelas, scarlatina, and other non-sporing pathogenic and non-pathogenic species." . . . "The result of all experiments on inhibition may be briefly summarized for all the twenty-five species tested—namely, (1) spores do not germinate in medicated gelatine or broth if the amount of disinfectant added be 0·1 per cent.; (2) no microbes (*Staphylococcus* and *Streptococcus*) are capable of growing in medicated gelatine or broth of the strength of 0·1 per cent. medication; (3) all non-sporing bacilli and spirilla fail to grow in the above 0·1 per cent. fluid; (4) excepted from this are the *Bacillus prodigiosus* and the bacillus of typhoid; the former shows growth on gelatine medicated 0·1 per cent.; the growth is retarded, and always starts from the superficial layer of the medium; it proceeds

[1] "Experiments on Izal," Nov. 1892.

considerably slower than on normal gelatine." He found, however, that 1 in 200 sterilized typhoid stools in 10 minutes.

Sheridan Delépine[1] decides that (1) "izal mixed with 10 parts of water will disinfect in 45 minutes dried tuberculous sputum or other tuberculous matter, and that fresh tuberculous sputum of great virulence when mixed with about an equal quantity of izal of the same strength as above, and allowed to dry at the ordinary temperature for 12 hours, is also completely disinfected": (2) "izal diluted with 200 of water is a safe germicide for micro-organisms as resistant or less resistant than B. coli communis": (3) when Staph. pyog. aureus dried on paper slips was steeped in 1:100 izal for 10 minutes, no growth could afterwards be obtained, therefore in this strength "it is a reliable antiseptic for the dressing of surgical wounds": (4) "in alkaline bouillon to which the 100th part of izal had been added it was impossible to get (anthrax) spores to show any sign of growth, even when kept at a temperature of 36° for 7 days, no precaution being taken to prevent volatilization. The spores, however, were not killed, for after thorough washing in sterilized water and cultivation in fresh bouillon, abundant growth was obtained."

In 1896 the author found in the emulsion as sold, in per cents.: ash 0·57, soda 0·17 to 0·21, acid oils 28, neutral and basic oils 2·92, water 46·5; emulsified with gelatine. 1 in 200 killed Staph. pyog. aureus and B. coli communis in less than ¼ hour, but did not kill spores of B. subtilis in 2 hours. The small quantity of soda distinguishes izal from preparations in which phenoloid acids are emulsified with a much larger quantity of soda or with soaps. Izal mixes readily with almost all fluids, even with dilute acids, without coagulating, hence it has a superior power over bacteria which develop acids in their growth, *e.g.*, Staph. pyog. aureus.

A report by O. de Meyer in 1897 on his experiments with Staph. pyog. aureus and citreus, Proteus vulgaris, and spore-bearing B. mesentericus vulgatus and anthracis, concludes that "creolin is more powerful as a germicide than carbolic acid, and that izal is more powerful than creolin." He does not state the source of the latter preparation.

[1] *Med. Chronicle*, Sept. 4th, 1895.

Klein's results have been confirmed by the later work of Houston[1] and of Thresh and Sowden.[2]

Dr. Bruce Clarke, of St. Bartholomew's Hospital, gave a very favourable report of the use of izal in surgery.[3] With regard to Dr. Klein's exceptions he says that they "obviously do not concern one from a surgical point of view, inasmuch as *B. prodigiosus* is not a pathogenic organism at all, and the bacillus of typhoid fever does not enter wounds."

He also observes that, "being an emulsion and not a clear solution, it is not so easy to see one's instruments when they are covered with it. At the same time it must be borne in mind that the very fact that the fluid is so singularly unable to form chemical compounds with living animal tissues is in all probability highly advantageous from the germicidal point of view. Unlike corrosive sublimate, which speedily loses its disinfectant power by combining with the albuminous substances of the body, izal retains this power in such a remarkable degree because it will not combine with anything. It is also at the ordinary temperature of the body non-volatile, as may be easily seen by placing a few drops on a piece of cotton wool and leaving it several months in an exposed position."

As to the effect of izal on higher animals, Dr. Klein reports that 0·25 c.c. of the 1 per cent. dilution, administered to rabbits either subcutaneously or by the mouth, had no effect on the rabbits' health or appetite. Mr. Worrall states that 10 drops have been taken with impunity. Dr. Tunnicliffe[4] gives the following table of the comparative toxicity and antiseptic power of various substances, the former in Bouchard's "équivalent toxique,"[5] or quantities per kilo of body weight required to produce the toxic effect.

Substance.	Toxicity.	Antiseptic power.
Izal emulsion	·5-1·5 C.c. pro kilo ...	1:200
Carbolic acid.....	·12 gramme	1:50
Guaiacol.....	·5 gramme	1:50
Veratrol	1·5 gramme	1:100
Biniodide of mercury	·015 gramme	1:4000
β-Naphthol.	3·00 grammes	1:1500
Strychnine	·0008 gramme.....	—

[1] *Practitioner*, Sept., 1902.
[2] *J. San. Inst.*, Jan., 1903.
[3] *Lancet*, July 1st, 1893.
[4] *Pharm. Journ*, April 18th, 1896.
[5] *Comptes rend.*, cv., 702.

"Strychnine has been introduced into this table to show the minimal poisonous dose of an active medicinal agent. From this table it will be seen that izal compares favourably with many other antiseptics. This method of comparison is, however, not free from error, and must be regarded as approximate and not absolute. The antiseptic power of any substance is not only different for different micro-organisms but for the same micro-organisms under different conditions, hence it is by no means a constant quantity. The same is true of the poisonous power of a substance. Such tables are, however, useful, and may be regarded as sufficiently accurate for practical purposes."

It is to be inferred that:—

(1) Izal seems, in a strength of 1 in 200, to be a disinfectant, and in 1 in 1,000 to be more antiseptic than phenol.

(2) Not being volatile it must be strictly local in its action, like chloride of zinc. Hence it is obvious that to "saturate a sheet and suspend it before the door of a room" has no beneficial action.

(3) The quantities recommended, namely, "for sprinkling rooms, 1 tablespoonful with 5 pints of water," and for sewers and public disinfection, "1 gallon in 100 gallons of water," are higher than those usually proposed for most other disinfectants, being about 1 per cent. As Dr. Rohe says,[1] "There can be no partial disinfection of infectious material; either its infective power is destroyed or it is not. In the latter case there has been a failure to disinfect, and the labour and money have been wasted."

"Okol" is a preparation by the Sanitas Company presenting some points of similarity with izal. The author found in it in 1897 (per cents.):—Acid and neutral oils 34, organic bases 0·35, nitrogenous matter 3·76, ash 0·94, water 60·95. The amount of nitrogenous emulsifying matter and of volatile bases is less than in izal. The bactericidal power was about the same and was much greater than carbolic acid.

EUCROPHENE, isobutylcresol hydriodide $[C_6H_3(CH_3)(C_4H_9)OH]_2$, HI, is a product of the action of iodine on isobutyl-orthocresol. It is insoluble in water and alkalies, but soluble in alcohol and ether. It easily decomposes (liberating iodine), and behaves like similar organic iodine compounds.

[1] *Text Book of Hygiene*, 1890, p. 350.

Di- and Tri-Hydroxybenzenes.

The poisonous effect of the hydroxybenzenes increases with the number of hydroxyl groups. The isomeric compounds, however, show exceptions. Phloroglucinol is less poisonous than pyrogallol. With the lower fungi, the higher hydroxy-derivatives are less poisonous than phenol.[1]

Resorcinol, or "resorcin," meta-dihydroxy-benzene, $C_6H_4(OH)_2$, occurs in minute needles, colourless when pure, but turning reddish in air. It coagulates albumen, forming a white precipitate. It only begins to be toxic in very large doses, 10 to 20 grammes per day internally for an adult, while a 2 per cent. solution is highly antiseptic (Vallin). Andeer,[2] Callias,[3] Dujardin-Beaumetz,[4] Lichtheim of Berne, and others have experimentally demonstrated that resorcinol is a powerful antiseptic. Callias proved that fermentation was prevented, and many animal liquids preserved, by 1 per cent. of resorcinol, while to keep milk required at least 2 per cent. As to its internal action, Andeer, after a dose of 10 grammes of resorcinol, experienced vertigo, dizziness, loss of smell, and salivation, the symptoms disappearing in 5 hours with no after effects. It is, therefore, far less poisonous than phenol. Dr. W. Murrel[5] also reported on its internal use. Dujardin-Beaumetz employed the fine powder in diphtheria and in syphilitic ulcerations with somewhat doubtful results. 1½ per cent. of resorcinol gradually entirely sterilized the bacilli of typhoid.

It is evident that 1 per cent. of this substance is efficiently antiseptic towards most micro-organisms. It has been employed in the treatment of acute fevers, also as spray in diphtheria and whooping-cough. As an antiseptic the dose is 5 to 20 grains. Weak solutions (1 to 3 per cent.) harden the skin while stronger ones (10 to 50 per cent.) macerate and destroy it.[6] Internally it has caused untoward effects.[7]

[1] K. Yabe, *Bull. Coll. Agric. Tokyo*, 1894. ii. 73; Biernacki, *Journ. Chem. Soc. Abstr.*, 1893, ii. 32; Loew, *Nat. System J. Giftwirk.*

[2] *Ueber das Resorcin*, Wurtzburg, 1880.

[3] *Resorcin en Thérapeutique*, Paris, 1881.

[4] *Bull. de Thérapeutique*, June and July, 1881.

[5] *Med. Times and Gaz.*, 1881, p. 486.

[6] Helbing's *Modern Materia Medica*, 1895, p. 146.

[7] *Lancet*, 1898, ii, 779, 836.

Andeer's lotion is resorcinol 40 grains, water 1 ounce, as an antiseptic and stimulant for foul sores, and to allay chronic eczema and psoriasis.[1]

The name "Resorcinol" has been very improperly given by M. Biálaieff to a mixture of resorcinol and iodoform for dressing wounds.[2]

"Anusol" is a bismuth iodoresorcinsulphonate, having a specific action on the rectal mucosa. It is described as a powerful disinfectant and deodorant for wounds, and in suppositories, and as free from unpleasant by-effects.

Catechol or pyrocatechin, ortho-dioxybenzene, $C_6H_4(OH)_2$, like almost all products of destructive distillation is antiseptic, but its properties in this respect do not seem to have been studied. The third dihydroxybenzene, hydroquinone or quinol, has also an antiseptic action. Its internal use in typhoid has been suggested, in doses of 3 to 8 grains.

J. R. Duggan[3] has investigated the relative amount of the three dioxybenzenes required to prevent *Bacillus subtilis* from developing in beef peptone. Taking phenol as 20, he finds the ratio of the three compounds ortho : meta : para = 20 : 25 : 30, whilst pyrogallol is represented by 15. Ratios of action on pathogenic bacilli are different.

Pyrogallol or "pyrogallic acid," trioxybenzene, $C_6H_3(OH)_3$ is inodorous, tastes astringent, and has less corrosive action than allied compounds. Its solution quickly turns brown in air, absorbing oxygen; if an alkali be present, the action is almost instantaneous, the solution becoming dark brown. This property leads it to be destructive to "aërobic" organisms—those which live in presence of oxygen. Bovet, of Neuchatel, first examined its antiseptic action,[4] and found that a 2 per cent. solution prevented putrefaction, fermentation, and mould for some months, and that 3 per cent. was capable of killing bacteria. Two per cent. solutions have no injurious local action and disinfect very well; but it cannot be used internally, as it reduces and destroys the blood corpuscles, causing hæmoglobinuria.

[1] Squire's *Companion to the B.P.*, 1899, p. 537.
[2] *Nouveaux Remèdes*, xii, 8.
[3] *Amer. Chem. Journ.*, vol. vii,, p. 62.
[4] *Revue d'hygiène*, 1879, p. 154.

It blackens steel instruments and stains the hands. The *British Medical Journal* recommends a 2 per cent. solution as an antiseptic (1879, vol. i., p. 278). "A 10 per cent, salve applied with a brush twice a day has been recommended in psoriasis,[1] but Neisser records a fatal case where it had been used freely as an ointment.[2]

Wood-tar and other Products.

The substances which are formed during the destructive distillation of wood in closed vessels are very numerous. They vary with the nature of the wood and with the temperature of the distillation, and are gaseous, liquid and solid. Charcoal, of course, is left behind in the retorts.

It may be mentioned here that the vapours from the destructive distillation of all organic bodies are antiseptic in nature, and many proposals have been made to utilize them by blowing them through sewage, etc., but the action is not sufficiently energetic.

The liquid portions are partly soluble in water. Wood spirit or crude methyl alcohol, CH_3OH, is obtained from them by distillation; it is strongly antiseptic, but is so volatile and inflammable that it is best used for other purposes.

Pyroligneous Acid (*vide* under *Acetic Acid* Chap. XI.), with methyl acetate and acetone, are also among the volatile products.

The insoluble portion, which consists of wood-tar, is composed of a mixture of various liquids, such as the hydrocarbons, toluene, xylene, cumene, etc. (the same as those from coal-tar, p. 198, but with little or no benzene), the substance called wood-creosote, and solids, such as paraffin, naphthalene, etc. The lower the heat used, the larger is the proportion of oxidized bodies formed, and the smaller that of hydrocarbons and gases. So that various specimens of wood-tar differ in composition.

Some of the coal-tar disinfectants previously described contain wood-tar products also.

[1] *Journ. of Pharm.*, vol. xxv., p. 377.

[2] *Zeitschrift f. klin. Med.*, 1879, vol. i., p. 88; Squire's *Companion*, 1890, p. 27; also *ibid*, 1899, p. 42.

The proportions of the different bodies obtained by distillation of wood are approximately as follow:—

Charcoal	25
Gases	22
Wood Spirit...	1·0
Acetic Acid	4·0
Tar	7·5
Water and other bodies	40·5
	100·0

Stockholm Tar, obtained from the resinous wood of the pine, is extensively used for preserving ropes and sacking. The smell is principally due to the constituents of creosote, notably to the crystalline body called pyroxanthin, which, though only present in small quantity, is said to be one of the best preservatives. Stockholm tar contains much resin, acetic acid, and oil of turpentine. When distilled it leaves a black resinous substance which constitutes ordinary pitch, and has been used in many patents for forming solid block disinfectants. The specific gravity of the ordinary wood-tar of commerce is about 1·04; when poured on water a portion floats and some dissolves, like saprol.

Retinol is simply the product of distillation of ordinary resin. Its antiseptic properties are feeble.

Resol is the name of a disinfectant somewhat analogous to lysol, which has been introduced from Germany. It is made by saponifying 1,000 parts of wood-tar with 9 parts of caustic potash, and adding 200 parts of "an indifferent body such as wood-spirit." The latter, however, adds considerably to the antiseptic power and aids in the saponification. Resol is said to be an active bactericide, killing typhoid, anthrax, and similar bacilli in five or ten minutes with a 3 per cent. solution.

Wood Creosote contains some phenol and cresol, and quantities of oxyphenols like guaiacol, creosol, and a little pyrocatechol. More antiseptic than coal-tar creosote, it has a different and more agreeable odour, but a more burning taste. It immediately coagulates albumen. It is not easily inflamed, but when kindled burns with a smoky flame: lamps burning creosote and spirit were among the early devices for fumigation, but they are sooty and as useless as

others of the kind. If swallowed in doses of more than a few drops it acts as a poison, so that its internal administration must be attempted with caution. Though sparingly soluble in water, the latter acquires from it its peculiar odour, pungent taste, and much of its antiseptic power. Alcohol and acetic acid dissolve it freely, so do the hydrocarbons of tar.

It combines with potash to form a crystalline compound; solutions of soda and ammonia also dissolve it. It is one of the most powerful antiseptics known. Meat that has been plunged into a solution containing 1 per cent. of creosote gradually becomes dry and hard on exposure to air, and acquires the flavour of smoked meat, but does not become putrid. A considerable proportion of creosote (from 1 to 1½ per cent.) is held in solution in the crude pyroligneous acid obtained during the destructive distillation of wood; and on saturating this acid at 167° F. with effloresced sodium sulphate, an oily matter which contains a large proportion of creosote is separated. Crude pyroligneous acid on this account is often employed for preserving hams and salted provisions, to which it communicates the same flavour as if they had been exposed to wood-smoke.

A great many patents relate to the manufacture of a disinfectant by distilling peat; this would be mainly creosote. Unfortunately the yield is small.

Creosote is used for carious teeth, for fœtid ulcers, and in many cutaneous affections, especially those that are parasitic.

J. Sommerbrodt, after nine years' trials, gave a most favourable account of its action in tuberculosis. In doses of 1 to 4 grains per day, in capsules with cod-liver oil, "it is well borne by the stomach and does not decrease the appetite."[1] Hoelscher and Seifert showed in 1895 that the good effects of the creosote or guaiacol treatment are due to its forming compounds, eliminable from the blood in a dissolved state, with the toxic albuminous bye-products of the tubercle bacillus. Creosote carbonate or "creosotal" (Chaumier) is recommended as freer from disturbing symptoms

[1] *Berlin Klin Wochenschr*, Oct. 10, 1891.

and quite as effective. "Oleocreosote" is a compound prepared by the aid of phosphorus trichloride: it splits up in the body into oleic acid and creosote, and is said to be tolerated in larger doses.

If applied to the skin in a concentrated state, creosote produces a white spot like phenol, and the skin peels off without any attendant inflammation. From its property of dissolving many organic bodies, such as camphor, the fatty and volatile oils, and many of the resins, it has been a frequent ingredient in compound antiseptic preparations. It is much more costly than the coal-tar product, hence could not be employed largely in public sanitation; and its smell in some cases has been known to produce nausea, headache, and vomiting.

Reichenbach in 1830 discovered the antiseptic powers of creosote; after a long trial it fell into discredit, and now is only employed for some of the uses above mentioned.[1]

Plants watered with creosote solution at once die; hence it cannot be used as a horticultural insecticide. Most micro-organisms are killed by it in a strength of $\frac{1}{3}$ per cent., and their spores are prevented from developing. In very small quantity it prevents fermentation, the action of diastase on starch, etc.

Bucholtz asserts that "1 in 1,000 was not sufficient to sterilize vegetable infusions; it required 1 per cent. to completely sterilize germs and bacteria."

Guaiacol, methoxy-phenol or methyl-catechol, $C_6H_4(OCH_3)OH$, is a colourless liquid, becoming brown in light (therefore should be kept in non-actinic bottles). Its odour and taste resemble creosote, of which it constitutes a large portion. It boils at 200° C. Only $\frac{1}{2}$ per cent. of it dissolves in water, but it is more easily soluble in alcohol, wood-spirit, acetic acid, and in alkalies. Sodium-guaiacol resembles sodium-phenol.

Ferric chloride gives a brown opacity with the aqueous, and a blue colour with the alcoholic solution; hot sulphuric acid gives an orange coloration. On shaking 4 c.c. of guaiacol with milk of lime (10 grammes lime in 10 c.c. of

[1] See a monograph by M. Labbée in the "*Dictionnaire des Sciences Médicales*," art. Creosote.

water) white crystals of a lime-guaiacol compound slowly form.

As the antiseptic value of wood creosote is due partly to the guaiacol which it contains, it is important to note that recently this ingredient has been removed from foreign creosotes.

The largest quantity (60 to 90 per cent.) exists in beech-wood creosote, but it also has been obtained by distillation of guaiacum resin, whence the name.

Its physiological value was first pointed out by Seidel in 1880. P. Marfori[1] finds that 1 part of guaiacol should dissolve in 60 of water, and that impurities render it more soluble. It first excites, then paralyses the nerve-centres, and reduces the temperature; therapeutically it is similar to phenol and pyrocatechol, but not so poisonous. In a later paper[2] the same author states that its antiseptic power is greater than that of phenol in the ratio of 5 to 2, and that 0·5 to 1 per cent. destroys *Bacillus tuberculosis* in two hours, while other bacteria are killed with their spores (?) in 20 to 30 minutes.

The hypodermic solutions known as Picot's, Pignol's, and Morel-Lavallee's contain guaiacol. It has been used for phthisis, administered in cod-liver oil or in weak spirit. J. J. Ridge finds that a solution in olive oil, 1 part in 80, is valuable for anointing the skin in smallpox.[3] "Eugoform" is an antiseptic dusting powder made by the action of formaldehyde on guaiacol and subsequent acetylization.[4]

Guaiacol-carboxylate, $C_6H_3(OH)(OCH_3).COOH$, is obtained by saturating sodium guaiacol with carbonic acid, heating, and precipitating by hydrochloric acid. It is, therefore, a methoxy-salicylic acid, and has naturally been credited with antiseptic and antipyretic properties.[5]

Creosol, or methyl-guaiacol, $C_6H_3(CH_3)(OCH_3).OH$, is the chief ingredient of ordinary wood-creosote. It resembles guaiacol, but has a higher boiling point, is heavier, and less soluble. Its antiseptic power is said to be a little

[1] *Chem. Centralblatt*, 1890, p. 155.
[2] *Ann. di Chimica*, 1891, vol. xiii., p. 3.
[3] *Brit. Med. J.*, 1903, No. 2212.
[4] *Deutsch. Med. Woch.*, 1900, 2111, 96.
[5] See also *Benzosol*, chap. ix., p. 267.

higher. A comparative study of creosol, guaiacol, and wood-creosote with and without the low boiling fractions, would be of value. A disinfecting fluid called "soluble creosote," containing some wood-creosote, is in the market.[1] The name "creosol" has been improperly given to a preparation of creosote with tannin, containing about 60 per cent. of creosote. It is a deep brown, amorphous, very hygroscopic powder, which is completely soluble in cold water, alcohol, and glycerine. The average dose is 3 grammes, in aqueous solution or in powder. It is given on the same therapeutic indications as guaiacol.[2]

"Little's Soluble Phenyle," made by Morris of Doncaster, was at one time in high repute in the north of England. It is recommended by Dr. Rohe as a good disinfectant at a strength of 2 per cent.[3] Prof. Corfield after lengthy experiments spoke highly of it. "It is non-corrosive and non-poisonous. 1 per cent. in water is more powerful than 10 per cent. of the best known antiseptics for wounds, ulcers, and for use at *post-mortems*. The powder is also energetic against vermin." It appears to be derived from wood-tar creosote, and would take rank with the other preparations.

Naphthalene Derivatives.

Bucholtz suggested that bodies with two "benzene rings" are more powerfully antiseptic than those containing only one such group, and that the toxic behaviour of such compounds is also less; but the opinion is not sound.

Naphthalene itself, $C_{10}H_8$, has been already described (p. 199). It is useful as an insecticide, but is not a disinfectant. Some commercial "disinfecting powders" have been proved to contain little else than naphthalene and earthy matters. It is hardly necessary to say they are practically useless. Dr. Mirovitch considers naphthalene of high value against ascarides and tape-worm, in doses of 15 grains, followed by a large dose of castor oil.[4] For

[1] *Chem. and Druggist*, Oct. 26, 1893.
[2] *Rev. de Thérap.*, xlii., 360.
[3] Rohe's *Hygiene*, 1890, p. 326.
[4] *Lancet*, 1891.

medical use it should have been carefully purified by crystallization from alcohol.

The observations of Pavas, Dor, Hess, Magnus, and Kolinski, among others, led to the conclusion that naphthalene is unsuitable for use in medicines, as it acts injuriously on the optic nerves and the retina, and upon the kidneys. A small quantity of camphor is said to largely cover its odour without affecting its value as a preventive of moth.[2] Tidy advocated the presence of naphthalene in the creosote used for preserving timbers.

Naphthalene-sulphonic Acids, $C_{10}H_7(SO_2 . OH)$.—By heating naphthalene with concentrated sulphuric acid, two isomeric acids of this formula are obtained. They are deliquescent crystalline substances, soluble in water, strongly acid, and almost inodorous. The sodium salt of the *β*-acid has been occasionally used as an antiseptic.

Naphthols, $C_{10}H_7 . OH$.—Each of the above sulphonic acids, when fused at a moderate temperature with caustic soda, yields the corresponding naphthol, or analogue of phenol. *β-Naphthol*, as being more abundant, is the commercial article. It crystallizes in lustrous plates, smells like phenol, and has a hot and tarry taste. It melts at 122° and boils at 286° C., but is readily volatile with steam.[3] It is almost insoluble in cold water, but dissolves in about 11 parts of boiling water, in 2 of rectified spirit, and 1½ of ether, 24 of chloroform, 12 of olive oil, and in 4 of glycerine. It is a powerful antiseptic, and was first proposed for skin diseases by Kaposi in 1881. It has been given internally in diarrhœa in an emulsion with oil, and is very effective in parasitic diseases and in chronic eczema[4] in ointment form (3 to 10 per cent.), or in alcohol solution (2 to 10 per cent.) (*Helbing*). A daily dose of 38 grains will produce intestinal antisepsis. It has also been given in typhoid fever.[5] In the presence of boric acid a solution of the strength of 1 grain in 2 oz. of lukewarm water may be made, which acts more

[1] Helbing, *Mod. Mat. Med.*, 1895, p. 113.

[2] See Fischer, *Med. Times and Gaz.*, 1881, p. 718, also *Squires Companion*, 1899, pp. 439, 440.

[3] For tests see *J. Soc. Chem. Ind.*, 1897, 894; *Chem. and Drugg.*, 1897, i, 422.

[4] *Med. Times and Gaz.*, 1882, vol. xi., p. 505.

[5] *Brit. Med. Journ.*, 1888, vol. xi., p. 1226.

energetically than either boric acid or naphthol alone (Anotta). A solution of 1 in 1,000, has been successfully used for preserving anatomical preparations.

Bouchard[1] says that he found 0·4 grm. of β-naphthol to have the same effect as ·025 grm. of mercuric iodide, 2 grms. of phenol, 1·6 of creosote, 1·27 of iodoform, 2·7 of iodol, or 1·51 of naphthalene, but these experiments are open to doubt, as they make naphthalene a stronger antiseptic than phenol. He values it highly for external use. "But what is more important is, that it appears to be the most efficient agent for intestinal antisepsis, on account of its slight solubility, which prevents its absorption, and allows it to remain a long time in the intestine without any poisonous effects." The British Pharmacopœia (1898) dose for internal antisepsis is 3 to 10 grains.[2]

Lesser and Neisser recorded symptoms of poisoning by β-naphthol, which Shoemaker attributed to impurities; a conclusion largely confirmed in 1888 by an exhaustive examination of this drug by Willenz.[3]

Dr. A. G. Gibson,[4] of the Edinburgh Medical Infirmary, used 2 grains of β-naphthol two or three times a day for the antiseptic treatment of pernicious anæmia. In a large number of cases, improvement was extremely rapid when iron had been used before. Dr. Gibson finds that irritation is sometimes caused by the drug, and to prevent this he administers it together with a bismuth preparation, such as the salicylate. α- and β-naphthols have an equal power in preventing the growth of Sp. choleræ (Stewart).

It has been recently observed that α-naphthol and salol (p. 269) when rubbed together form a liquid. β-naphthol, on the other hand, does not liquefy, but, like many other substances, it becomes a permanent fluid when melted with camphor, so forming "camphorated β-naphthol," used, according to Fernet, with great success for boils, coryza, angina diphtheritica, and tuberculosis. Against the latter it was given by injection in doses of 2 grms. mixed with oil.

[1] *Report Acad. des Sciences*, 1888.
[2] *Brit. Med. Journ.*, 1888, p. 1185.
[3] Helbing, *Mod. Mat. Med.*, p. 118.
[4] *Edin. Med. Journ.*, October, 1890.

Reboul cured twenty-one out of twenty-seven cases of tuberculous glands by emptying any abscess formed, and injecting 7 or 8 drops of camphorated naphthol, repeated every two days. Similar results are recorded by Nelaton.[1]

Betol, β-naphthol salicylate, $C_6H_4(OH).CO.OC_{10}H_7$, is antiseptic, and somewhat similar to salol, but less soluble, and is now almost disused.

"Microcidine," chiefly composed of sodium-β-naphthol, $C_{10}H_7ONa$, also contains phenols. Prepared by the action of soda and heat on β-naphthol. It is more soluble but less antiseptic than the latter, and is somewhat irritant and caustic. It possesses no special advantage.

Naphtholsulphonates.—Salts of the β-acid have been introduced under the names of "asaprol" (calcium), "quinaphthol" (quinine[2]), and "alumnol" (aluminium). The latter is a white powder containing 5 per cent. of Al, very soluble in water, and slightly acid. It is astringent and antiseptic, and precipitates albumen and gelatinous bodies, but the precipitate re-dissolves in excess of albumen or gelatine, hence it has considerable penetrative power. Helbing states that in 1:10,000 solution it retards the development of gonococci, pus cocci and allied bacteria, and in 1 in 250 prevents all growth. Heintz and Liebrecht found that very large doses are required to produce any toxic action on animals.[3] It has been used with success in surgical dressings, for washing out cavities, and as a gargle.[4]

Hydronaphthol seems to be β-tetrahydro-naphthol, $C_{10}H_{12}O$, obtained by the reduction of β-naphthol by sodium. It forms white shining crystals with an odour something like creosote, slightly soluble in water, easily in spirit. Dr. Bryce recommends the external use of 1 part of hydronaphthol dissolved in 10 parts of rectified spirit, to which sufficient glycerine is added to make a 1 per cent. solution. "In this form the antiseptic properties are well marked." Dockrell has used it very successfully in a plaster against *Tinea tonsurans*. Mr. M. Clarke found it of great value in enteric fever and diarrhœa. He says that it has a very

[1] Helbing, *loc. cit.*

[2] "An intestinal antiseptic useful in typhoid," *Pharm. Journ.*, 1897, ii., 83.

[3] *Pharm. Centralhalle*, 1892, p. 697.

[4] *Chem. and Drug.*, Jan. 21, 1893; *Lancet*, April 21, 1894.

distinct retarding effect on digestion, but does not much interfere with that of milk. Edington's experiments (about 1890) attributed a remarkable antiseptic power to hydronaphthol.

Hydronaphthol gauze 5 per cent. is recommended as very lasting, and as compatible with albuminous fluids.[1]

α-Hydroxynaphthoic Acid, called also simply oxynaphthoic acid, $C_{10}H_6(OH).COOH$, is the analogue of salicylic acid, formed by the action of carbonic acid on sodium-naphthol. It melts at 186° C., is sparingly soluble in water, but easily in alcohol, ether, and the alkalies. Collodion impregnated with ½ per cent. of it has been used as a substitute for iodoform-collodion, as it is non-irritant and more stable.[2] A 5 per cent. ointment is antiseptic in scabies. Ellenberger and Meister established its bactericidal properties.[3] It has been proposed at various times as a preservative, but it is very difficultly soluble, is only effective in the free state, and is not innocuous.

CHAPTER IX.

ORGANIC SUBSTANCES *(continued)*.

Nitro-Compounds: Nitro-Benzene—Nitro-Phenols—Trinitro-Phenol or Picric Acid; its value as an insecticide—Nitro-Cresols—Nitro-Glycerine—Nitro-Cellulose—Collodion. Amido-Compounds: Ammonia—Compound Ammonias—Amines—Amides—Amido-Acids—Hydroxylamine—Hydrazine—Methylamines—The "Amines Process"—Aminol—Urotropine—Aniline—Acetanilide—*Aniline Dyes as Antiseptics*—Methyl-Violets—Pyoctanin—Apyonin—Toluidine and Methylene Blues. Pyrrol-Compounds: Furfurane—Thiophene—Pyrrol—*Iodol* or Tetra-Iodo-Pyrrol—*Antipyrin* or Phenazone—Salipyrin, etc. Pyridine Group, etc.: Conine—Piperine—*Pyridine*—Antiseptic properties of Tobacco-smoke—Nicotine—Various Patents as to Pyridine, etc.—Indole—Tyrosine—*Quinoline* or Leucoline—Diaphtherin—Loretin—Thalline—*Chinosol*—Quinine—Anti-septol—Fluorescent Compounds.

Nitro-Compounds.

The aromatic nitro-compounds are characterized by their poisonous properties. Several of them have been suggested as disinfectants.

[1] S. W. Williams, *Chem. and Drug*, 1893, p. 735.
[2] *Ibid.*, 1889, p. 34.
[3] *Journ. of Soc. of Chem. Industry*, 1888, p. 226.

Nitro-Benzene ("Nitro-Benzol"), $C_6H_5(NO_2)$, is a heavy yellowish oil smelling like bitter almonds. It is a disinfectant, because it kills bacteria, but its strong odour, poisonous character and insolubility render it unsuitable for general use. Pettenkofer and Lehmann[1] state that the vapour of nitro-benzene "even in large quantities had no serious effect"; but many aniline workers have experienced that it is nauseating and narcotic. The same may be said of Nitro-Toluene, $C_6H_4(CH_3)(NO_2)$, etc., and most of the di- and tri-nitro-compounds.

Ortho- and Para-Nitrophenols, $C_6H_4(NO_2)OH$, are slightly soluble in water, acid, germicide, and poisonous. Their sodium compounds are soluble and antiseptic. There are no records of bacteriological experiments with reference to them.

Trinitrophenol, "picric or carbazotic acid," $C_6H_2(NO_2)_3OH$, occurs in pale yellow plates, and is very acid, little soluble in water (about 1½ per cent.), but soluble in alcohol. Its salts are yellow and explosive. It is a very powerful germicide, and almost immediately combines with albuminoid substances, staining them yellow, precipitating the albumens, and causing the death of protoplasm in a similar way to iodine; hence it is rapidly fatal to both bacteria and spores. The aqueous solutions are extremely poisonous, irritant, but not corrosive.

Jalan de la Croix[2] found that bacteria in white of egg infusions were killed by 1 in 1,000 of picric acid, but resisted 1 in 5,000. He also points out that a solution of 1 in 200 prevents growth in bouillon, while ½ to 1 per cent. was required to destroy the germs; this would be a nearly saturated solution in water. Cheron[3] disinfected the latrines of a hospital by the use of 10 litres of a saturated solution (1½ per cent.). He found that it arrested fermentation, and the action of diastase and synaptase. The germination of seeds was also prevented. It hindered the ammoniacal change in urine, even in cases of vesical catarrh, when given to a patient, or injected into the bladder. Schwartz asserted

[1] *Acad. d. Wissensch. zu München*, 1887, p. 179.
[2] *Arch. f. exp. Pathol.*, Jan. 27, 1881.
[3] *J. de Thérapeut.*, Gubler, 1880, p. 121.

(1880) that a minimum dose of 1 in 15,000 of picric acid killed the bacteria of tobacco infusions transferred to Pasteur's solution, whereas Kuhn maintained that 1 in 1,000 was necessary, thus agreeing with Jalan de la Croix.

Picric acid is used in histology for hardening and preserving tissues, also in acute eczema.[1] Vallin states[2] that 60 centigrammes per day produce in man, besides a deep orange colouration of the skin and urine, a slowing and weakening of the heart, prostration of strength, vertigo, and stupefaction.

Kinloch patented picric acid as "an insecticide," antiseptic and disinfectant.[3]

Except as an insecticide, when its staining powers and poisonous action on plants and animals would be against its use, picric acid may be pronounced to be unsatisfactory for disinfection. There is still, however, a possibility of its being of special service in killing those micro-organisms that only mercuric chloride will touch, as Klein has shown, with some difficulty. Further experiments would be desirable. For its use in antiseptic dressings see *Year Book of Pharmacy*, 1898, 250. Picric acid has recently been used very successfully in the aseptic treatment of burns.[4] One hundred cases have been treated in Leith Hospital.[5]

Potassium Dinitro-Ortho-Cresol, $C_6H_2(NO_2)_2(CH_3)OK$, occurs in yellow needles, inodorous, sparingly soluble in water, poisonous, and explosive by heat. It is used as a yellowish paste, mixed with soap and glycerine, and thus dissolves easily in water. It was introduced into this country under the commercial name of "Antinonnin" (F. Bayer & Co., Elberfeld). "Properly diluted it forms an efficacious and safe insecticide, and does not injure plants. Though originally intended to destroy certain kinds of caterpillars it has been found to be fatal to mice, ants, snails, and all kinds of plant-lice, as well as protecting wood from dry rot and fungi. 1 kilo. of antinonnin in 300 litres is found most effective for killing lower plant life and fungi. House and field mice

[1] *Brit. Med Journ.*, 1897, i., 331, 457.
[2] *Désinfectants*, p. 156.
[3] Patent No. 6,243, 1894.
[4] *Nouv. Remédes*, August 24th, 1897, p. 481.
[5] *Brit. Med. Journ.*, July 17th, 1897.

succumb to three-twentieths of a grain, best mixed with flour-paste."[1] The specification states that "1 in 400 of water kills all insects, also fungi which rot timber; it may even be used more dilute if time be given. Soft soap, ¼ part, increases the power." Hary and v. Miller[2] state that a solution of "antinonnin" in soap water of 1 in 1,500 to 1 in 2,000 is destructive to all common injurious parasites on plants, without affecting the latter. Aubry finds that when yeast is treated with this substance the bacteria present are destroyed though the yeast itself is uninjured by even a 5 per cent. solution.

There are a large number of other nitro-compounds of the aromatic group, of similar properties, but of no special interest.

Nitroglycerine, $C_3H_5(O.NO_2)_3$, is said to be antiseptic when dissolved in alcohol and poured into water.

Nitrocellulose dissolved in ether or acetone is used under the name of *Collodion* for protecting wounds, etc. Being insoluble in water and the blood it has no antiseptic power, but may be made a medium for antiseptics.

Amido-Compounds.

Ammonia, NH_3, has been described among the alkalies (p. 151). It, like other products of putrefaction, is fatal to the bacteria which produce it, and the bactericidal power of ammonia, sulphuretted hydrogen, and even of carbonic acid no doubt materially assist in retarding natural decay. Animal matter placed in a 5 per cent. solution of ammonia, remains free from putrescence for a long period. When added to gelatine in which putrefaction had been already set up, a 5 per cent. solution caused the putrefaction to cease. In an atmosphere impregnated with ammonium carbonate, meat can be kept for six months, and at the end of the time remain unputrescent.

In all these cases it is necessary that the material be kept enclosed, or the ammonia would rapidly escape. On account of its alkalinity, smell, and irritant action, it has not been much used. The fact that its vapour, which is at first

[1] Patent No. 3,301, 1892.

[2] *Münch. Algem., Zeit.* ; *Pharm. J.*, [4] i., 365.

stimulant, soon becomes excessively depressant, also militates against its use for rooms. The compound ammonias, or amines, formed by replacing successively the atoms of hydrogen in ammonia by basic organic radicles, have greater antiseptic properties. Methylamine, $NH_2(CH_3)$, the simplest of these amines, is a gas; others are more or less volatile liquids; while the more complicated organic bases, like the alkaloids, are white solids. They are all alkaline, form salts with acids, and the volatile ones have an ammoniacal odour. As a class they are poisonous, therefore they are antiseptic and may be disinfectant. They absorb sulphuretted hydrogen, but of course do not absorb ammonia.

The acid organic radicles, such as acetyl ($CH_3.CO$), may also replace the hydrogen in ammonia, forming a class of bodies called amides, *e.g.*, acetamide, $CH_3.CO.NH_2$, which are usually crystalline, neutral compounds which are soluble in water and more or less volatile. A few, like acetanilide, are antiseptic.

Hydroxylamine, NH_2OH, has been tried by Bing and others in skin diseases. It acts as a reducing agent, is poisonous, and is a strong germicide.

Hydrazine or Diamine, N_2H_4, has been found by Loew and Buchner to be powerfully poisonous to animal, vegetable, and bacterial life.

Mono-, Di-, and Tri-methylamine, $NH_2(CH_3)$, $NH(CH_3)_2$ and $N(CH_3)_3$, are gaseous at ordinary temperatures and very soluble in water. The solutions are powerfully alkaline, caustic when concentrated, and have an ammoniacal and fishy odour like herring-brine, in which they are contained. They are poisonous to bacteria and lower life, but have not been much used on account of several inconveniences. Hugo Wolheim, in patents 15,321 and 16,242 of 1888, claimed herring-brine and liquids prepared from it, "for destroying, in a very short time, the vitality of all germs and spores which can produce disease." This was the foundation of the "Amines" process for treating sewage with herring-brine and lime. This liquid is a mixture of amines, with trimethylamine predominating. Klein and others, who tested the effluent bacteriologically, reported very favourably on the process, asserting that the result was complete sterilization, that 1 per cent. of trimethylamine was sufficient,

and that the operation was easy and inexpensive. Objections were made by others on the score of (1) the offensive odour of the precipitant; (2) its deterioration on keeping; (3) in the case of its application inland, the quantity of salt that must be discharged into rivers; (4) the danger of the effluent being poisonous to river-fish (this is not proved of the small quantity of trimethylamine that would remain as, being volatile, most of it evaporates into the air); (5) the alkaline character of the clarified water; and (6) the difficulty of procuring a sufficient supply of herring-brine.

"Aminol" is the name given to the liquid obtained by distilling herring-brine with lime, according to the patent mentioned above. It is a clear colourless liquid, alkaline and odorous of the bases. It is permanent when kept tightly enclosed, but easily loses strength when opened. Two solutions are applied:—"D" for general disinfecting purposes, and "R" for medicine and surgery. Klein has obtained better results with Aminol on anthrax spores than Koch using trimethylamine.

Amylamine, $(C_5H_7)NH_2$, is contained in the products of destructive distillation of animal matters, such as bone oil. It is a liquid smelling like burnt feathers, is antiseptic, but seems to have no special advantage.

Urotropine, hexamethylenetetramine, $C_6H_{12}N_4$, obtained by the action of ammonia on formaldehyde, is a white readily soluble inodorous crystalline powder, and its formation is the reason why ammonia is useful to remove the odour of formaldehyde after disinfection of rooms by the latter agent. It is serviceable as an antiseptic in cystic affections. Since the typhoid organism has been found to persist in the urine for a long time after recovery from the disease, it is a customary precaution to administer urotropine for a number of weeks to prevent the spread of infection from this cause. Dr. Stern, indeed, gives a warning against this practice,[1] as not being safe, but advocates, rather, the careful external disinfection of the urine of typhoid patients. This can be done by adding 1 per 1,000 of sulphuric acid (Chapter XII.).

The dose of urotropine is 7 grains, but "15 to 20 grains or more may be taken without harm for a long period."[2]

[1] *Therapist*, March 15th, 1902, p. 52.
[2] Squire's *Companion*, 1899, p. 308.

Loew and Bokorny state that it acts nutritiously on algæ;[1] which suggests a trial for curing bacterial disease in aquaria and fish-breeding tanks. This substance enters into a large number of derived antiseptics.[2]

"Helmitol," anhydromethylene citrate of hexamethylene-tetramine, is a new antiseptic for urinary diseases.

"Sublamin" is a compound of mercuric sulphate and ethylene diamine, $C_2H_4(NH_2)_2$, recommended as non-irritant and not coagulating albumen. With or without alcohol it was found by Drs. Danielsohn, Hess and Fürbringer to have great advantages over corrosive sublimate for disinfecting the hands.[3]

Aniline, amidobenzene, or phenylamine, $C_6H_5(NH_2)$, has been tried in France as a disinfectant, but has great disadvantages. It is poisonous, and hence a germicide. It slowly volatilizes at ordinary temperatures, giving a vapour of oppressive tobacco-like odour, which kills bacteria, but does not easily affect their spores. Pettenkofer and Lehmann assert[4] that 0·1 per cent. of aniline vapour in air is dangerous to man and animals. From this fact, and the slow rate at which it diffuses, its use for fumigation is negatived.

The salts are antiseptic, and, being acid, absorb ammonia and compound ammonias, but not sulphuretted hydrogen. Angus Smith[5] places aniline in his sixth class—*i.e.*, as moderately antiseptic. Dr. Fischer has shown that tubercular sputum mixed with ten times its volume of aniline water, is completely disinfected in twenty-four hours. This is equivalent to the action of a 5 per cent. carbolic acid.

Substitution Products.—An immense number of these have been obtained, aniline being much more easily acted upon than benzene. They are generally antiseptic, but have hitherto not yielded any satisfactory results for hygienic purposes, and are often less soluble and volatile, and more poisonous than aniline itself.

[1] *Journ. f. prakt. Chem.*, [2] xxxvi., 272.

[2] *Chem. Zeit.*, 1901, xxv., 1045.

[3] *Therapist*, May and June, 1901; Dec. 15th, 1902.

[4] *Acad. d. Wissensch. zu München*, 1887, p. 179.

[5] *Disinfectants*, Edin., 1869.

Acetanilide, "antifebrin," or phenyl-acetamide, $C_6H_5.NH(CO.CH_3)$, a white crystalline and easily soluble powder, as an antiseptic for wounds has been found to produce poisonous symptoms.

Para-brom-acetanilide, $C_6H_4Br.NH(CO.CH_3)$, "asepsin," or "antisepsin," is said to be anodyne and antiseptic. (Note similar names, pp. 139, 143, 155, 185, 212, 263).

Aniline Dyes as Antiseptics.—Several of these have long been known to have the power of penetrating into living animal and vegetable structures, different dyes selecting different parts and species; therefore, they are widely employed for microscopic staining. Their action occurs in extremely dilute solutions, and is out of all proportion to their poisonous action on higher animals.

The effect is to lower the vitality of, and, finally, to kill the organisms. Hence it became a matter of interest to see how far they could be used as actual disinfectants. Koch proved[1] that a number of the tar dyes were inhibitory to tubercle and other bacilli, both in local and in internal application. Professor Stilling, of Strasburg, has found that a paste made with wheaten flour, with a 2 per 1,000 solution of methyl-violet added, keeps for an indefinite time. Milk mixed with the same quantity does not turn sour, butter and bacon soaked in a stronger solution (1 in 500) and dried, are superficially stained, but do not afterwards become rancid. *Mucor stolonifer* was sown upon rolls of bread, some of which were soaked in a 1 in 500 to 1 in 1,000 solution of the dye, and some in water only. On the latter a growth appeared in twenty-four hours, whilst on the former none could be noticed after fourteen days. He has given the name of "pyoctanin," from πυος, pus and κταος, stain, to a pure methyl-violet from Merck, of Darmstadt. "Certain auramines proved to be the next best, when used in solutions of 1 in 4,000 to 1 in 1,000."[2]

Dr. C. Prioux[3] points out that 1 in 100 solutions of pyoctanin and gentian violet prevent the development of micro-organisms. Weaker solutions (1 in 500, or even 1

[1] *Mittheil. a. d. K. Gesundh.*, 1881, vol. i., p. 234.

[2] *Lancet*, 1890, vol. xi., p. 965.

[3] *International J. of Microscopy and Nat. Science*, vol. iii., part 18.

in 2,000) arrest the cultures of typhoid and *B. coli communis*; 1 per cent. solutions of safranine (an orange-red dye of definite constitution) have also been shown to hinder Eberth's bacillus from developing.

Solutions of "blue pyoctanin" for general surgery, ointments, powders, and dressings have been introduced. Dr. Petersen found that these preparations were as effective as those made with iodoform, without the unpleasant odour, and without any bad effects or symptoms of poisoning. Dr. Wanscher strongly recommended a 1 per cent. solution for ophthalmic use and in urethral discharges, as lessening local irritation. They have also been used for nasal and other cavities of the body, to stop suppuration. Von Mosetig treated malignant tumours by injections of methyl-violet, and believes that complete cure by this method is possible.

Yellow Pyoctanin is an "auramine," of the formula $C[C_6H_4 . N(CH_3)_2]_2 . NH$. It is a para-derivative of benzophenone, and is specially recommended for ophthalmic practice.

"Apyonin" is said to be also an auramine, and is intended for the same purpose as the last.

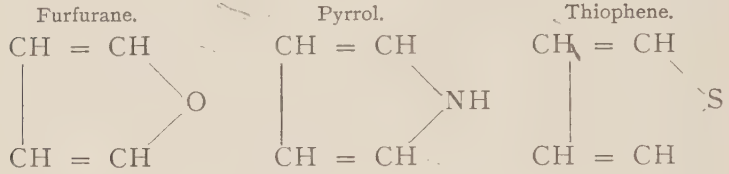
Toluidine Blue, the double chloride of zinc and dimethyltoluthionine, is said by Veasey and Schweinitz to be a powerful poison to organisms of low development. In ophthalmic practice it may be employed in a similar manner to methylene blue for infectious conjunctivitis and inflammatory affections. Dilutions of 1 per mille are sufficient to arrest the formation of pus, without exciting any irritation on the tissues. Before application, the eye should be well bathed with physiological salt solution. Stains on the skin may be removed with water. Toluidine blue may also be used as a substitute for fluorescein for detecting the seat and extent of corneal lesions, since it does not affect the normal cornea. The injured parts are revealed by the deep blue staining.[1]

Methylene Blue, with atropine and benzoic acid, was according to Lieut. Lelean, the only drug he had found of use against *Bilharzia hæmatobia*.[2]

[1] *Merck's Report*, 1899, 45.
[2] *Lancet*, May 3rd, 1902.

Pyrrol Compounds.

There are other rings analogous to the benzene ring, but containing 4 or 5 atoms instead of 6. Those with 4 carbon atoms include these three chief compounds:—



All three are tar products, are volatile, colourless liquids, with antiseptic characters that have not been well studied.

Furfurane, C_4H_4O, appears to be present in pine-wood tar. Furfurol, $C_4H_3(CO.H)O$, is the corresponding aldehyde.

Thiophene, C_4H_4S, is found in commercial benzene, and smells like it; it boils at 84° C. It is probably an insecticide if not a germicide. It is insoluble in water, but soluble in oil of vitriol, forming a sulphonic acid, $C_4H_3S(SO_3H)$.

"Iodol," tetra-iodo-pyrrol, $C_4I_4(NH)$, is a pale yellow, inodorous and tasteless, crystalline powder, almost insoluble in water. It is reputed to have antiseptic properties, and is used for the same purposes as iodoform, but has not the objectionable smell, and is not so poisonous, but Riedlin says[1] that it has no action on cholera or any other bacteria.

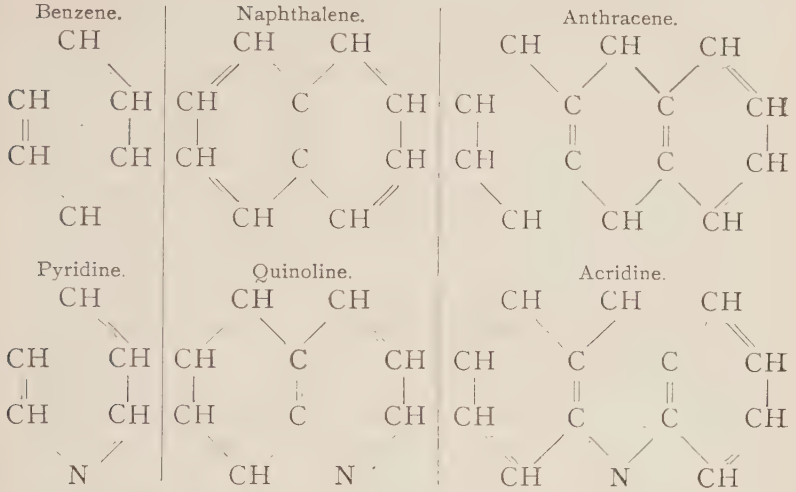
"Antipyrin," $C_{11}H_{12}N_2O$, or "phenazone," externally has found favour as an antiseptic lotion, and as gauze. Nitro- and "isonitroso"-antipyrin, "salipyrin" (a salicylate), "iodantipyrin" or "iodpyrin," "resopyrin" (a compound with resorcinol) have been prepared.

Pyridine Group, etc.

If, in the benzene ring, nitrogen be substituted for a CH group, pyridine, C_5H_5N, is obtained. From naphthalene

[1] *Archiv. f. Hyg.*, vol. vii., p. 309.

and anthracene, similar nitrogen derivatives are formed:—



Additive compounds, of which piperidine or hexahydro-pyridine, $C_5H_{10}NH$, and nicotine or hexahydro-dipyridyl, $(C_5H_4N)_2H_6$, are examples, are also known. The radicles, methyl, ethyl, etc., can also replace the hydrogen atoms giving homologues of pyridine, which exist with it in coal-tar, and in larger quantity in bone-oil. They much resemble pyridine in properties, but rise in boiling point and diminish in density as the number of carbon atoms increases, and are more readily oxidized and attacked. The mono-, di-, tri-, tetra-, and penta-methyl derivatives have been obtained by the fractional distillation of bone-oil, the fractions so procured being mixtures of isomerides, which it is impossible to separate by this method.

TABLE OF THE PYRIDINE HOMOLOGUES.

Name.	Constitutional Formula.	Empirical Formula.	Boiling Point.	Specific Gravity.
Pyridine, ...	... ...	C_5H_5N	117° C	·985
Picolines, ...	$C_5H_4(CH_3)N$	C_6H_7N	135°	·961
Lutidines, ...	$C_5H_3(CH_3)_2N$	C_7H_9N	154·5°	·946
Collidines, ...	$C_5H_2(CH_3)_3N$	$C_8H_{11}N$	180°	·944
Parvolines, ...	$C_5H(CH_3)_4$	$C_9H_{13}N$	...	...
Coridines, ...	$C_5(CH_3)_5N$	$C_{10}H_{15}N$	211°	...
Rubidine, ...	$?C_5(C_2H_5)(CH_3)_4N$	$C_{11}H_{17}N$	230°	...
Viridine, ...	$?C_5(C_3H_7)(CH_3)_4N$	$C_{12}H_{19}N$	251°	...

Conine, $C_8H_{17}N$, the volatile alkaloid of hemlock (*Conium maculatum*), is normal-propyl-piperidine, $C_5H_{10}N(C_3H_7)$, (*Ladenburg*).

Piperine, from pepper, is piperyl-piperidine, $C_5H_{10}N$-$C_{12}H_9O_3$.

It will be noticed that aniline, $C_6H_5(NH_2)$, is metameric with the picolines, $C_5H_4(CH_3)N$, of which all the three possible isomerides have been separated from bone-oil.

All these substances are more or less narcotic poisons; hence, would act as antiseptics, and, if in sufficient quantity, would kill bacteria. It has been mentioned that *Saprol* (p. 225) contains pyridine bases: from most coal-tar disinfectants they have been removed together with aniline by treatment with acids, but some of the newer preparations contain appreciable quantities of these bases. The most important is—

Pyridine, C_5H_5N.—When pure it is a mobile, colourless liquid, which does not turn brown in air and light, and is slowly and completely volatile. Its odour is said to be "empyreumatic," but is most persistent and unpleasant. It absorbs water from the air, and mixes with it in all proportions; it is also readily soluble in alcohol. It forms soluble crystalline salts with acids. Commercial ammonia often contains pyridine, and commercial pyridine is sometimes contaminated with ammonia.

Tobacco-smoke, contrary to popular belief, does not contain nicotine, which is decomposed by the heat, but pyridine and its homologues, and the beneficial effect of tobacco in many cases of asthma, must be attributed to these latter, whether as sedative or as bactericide (it must be remembered that very little of the smoke itself gets into the lungs). Pyridine inhalations have been proposed for asthma. "From 1 to 1½ drachms are poured on a plate and placed in a room with the patients. At 68° to 77° F. the above quantity evaporates in about an hour. It is said that after a few minutes' exposure to the pyridine atmosphere the remedy can be detected in the urine. The treatment was well spoken of by Dr. Kelemen, among others, but does not seem to have maintained its ground. The vapour is apt to cause headache. Pyridine mixed with a little oil of peppermint has been employed in the treatment of diphtheria with some success, and in aqueous solution (1 in 300) three or four

injections have been recently said by Rademacher to be sufficient to cure gonorrhœa."[1]

It was stated by the Cigar Manufacturers' Association of Hamburg that in the last visitation of cholera there were only eight cases and four deaths amongst a body of 5,000 cigar-makers.

Dr. Burney, the senior Medical Officer of Greenwich Workhouse, asserts that the tobacco-smoking inmates enjoyed comparative immunity from epidemics, and tobacco-smoking is believed to have had a disinfectant action in cases of cholera and other infectious diseases. But Dr. Kerr points out that if a man cannot stand smoking, it may depress his heart action and enfeeble his constitution, and so lessen the resisting power to throw off the noxious germs. Pyridine fumigations are also open to the same objection. It is recorded that Tessinari found that tobacco-smoke, on being passed through tubes containing a nutrient gelatine and pathogenic germs for from ten to thirty minutes, destroyed the bacilli of Asiatic cholera and of pneumonia. Pyridine was introduced by O. Fergusson as a horticultural insecticide about 1890, but its odour was against it, although it was most effective. Wynter Blyth exposed the yellow bacillus of nasal catarrh, on threads, to the action of a 1 per cent. solution of a mixture of pyridine, collidine, lutidine, and acridine from bone-oil. After the threads were washed and transferred to nutrient gelatine, there was no growth. In sour milk also, pyridine inhibited growth. Tobacco-smoke passed through water killed the yellow bacillus. These experiments tend to confirm the idea that disinfectant preparations containing the basic constituents of coal tar are to be preferred to those only containing the phenols, also that pyridine, being very soluble in water and non-irritant, might be of service in nasal affections.

NICOTINE, $C_{10}H_8(H_6)N_2$, is an oily liquid which rapidly turns brown in air. It boils at about 250° C., but is readily volatile with steam. It has a well-known stupefying odour, is alkaline, dissolves easily in water, alcohol and ether, forms crystalline salts with acids, and is extremely poisonous. Its use in gardening is familiar. A tobacco-juice insecticide

[1] Helbing, *Mod. Mat. Med.*, p. 65.

is sold in France under a government guarantee as to the amount of nicotine it contains.[1]

Nickels[2] covers the use of shale or bone-oil, or pyridine bases, with resin and soda, as a disinfectant. Overbeck[3] proposed the use of pyridine or leucoline (quinoline, see below) with chalk or lime.

Indole $C_6H_4 \langle \begin{matrix} HN \\ CH \end{matrix} \rangle CH$, crystallizes in plates, moderately soluble in water, feebly basic, and readily volatilizing with steam. Since it is a product of putrefaction, and is produced by members of the *Coli* group, by Sp. choleræ (along with nitrite), and by some others, it has been inferred that indol itself would be antagonistic to organisms. But it is found that in impure cultures the indol first formed gradually disappears, while the organisms remain. In any case its peculiar fæcal odour would preclude its practical use.

Tyrosine, $C_6H_4(OH).CH_2(NH_2).COOH$, β-oxyphenol-amidopropionic acid, is also a constant product of the putrefaction of albuminoid substances, and has been said to be strongly antiseptic. It crystallizes in minute needles, which are inodorous, almost tasteless, and nearly neutral. It seems to be worthy of experiment.

Quinoline Derivatives.

Quinoline, chinoline, or "leucoline," C_9H_7N, is a colourless, highly refracting, oily liquid of a disagreeably pungent and aromatic odour, and a bitter acrid taste. In light and air it rapidly turns brown. It melts below 4° C., boils at 237° C., and has a specific gravity of 1·081.

It dissolves sparingly in water, easily in alcohol, etc., to an alkaline solution, and with acids forms soluble crystalline salts. The salicylate and tartrate have been used occasionally in medicine, both internally and externally. Quinoline occurs in coal-tar, etc., with two homologues, lepidine, $C_{10}H_9N$, B.P. 265°, and cryptidine $C_{11}H_{11}N$, B.P. 274° C. It derives its name from having been first obtained by distilling quinine with potash. Quinoline is incompatible

[1] *J. Soc. Arts*, 1899, xlvii., 901.

[2] Patent No. 3,053, 1883.

[3] Patent No. 3,199, 1883.

with oxidants, with iodine solutions, and with metallic salts; it is antiseptic, and is the subject of the following patent[1]:—"It has been proved that quinoline and toluquinoline possess great antibacterial properties, but the complete insolubility of these substances in non-acid fluids presented a serious obstacle to their use. This invention consists of using as a solvent soap in the nascent state," as in creolin, etc., "50 kilos of castor oil, 50 of quinoline, by the clearing of the liquid, which is then diluted with 85 kilos of water." Quinoline does not saponify, so that the solution would contain 20 per cent. of quinoline dissolved in aqueous soap, and would become turbid with water like creolin. According to Donath, 0·2 per cent. of quinoline prevents the putrefaction of urine, and 0·4 per cent that of blood.

α-Oxy-quinoline or carbostyrile, $C_6H_6(OH)N$, occurs in white needles, melting at 198°, and is strongly antiseptic. It is the source of:—

"Diaphtherin," introduced by Prof. Emmerich and Kronacher, of Munich,[2] who after extended trials, pronounced it to be "equal, if not superior, to previously known antiseptics." It is said to be di-oxy-quinoline ortho-phenol-sulphonate $[C_9H_6(OH)N]_2C_6H_4(OH).HSO_3$. It is a yellow powder, readily soluble in water, decomposed by alkalies and even by blood, with elimination of sparingly soluble oxyquinoline in a fine state of division; hence, when applied to wounds, it does not lose its antiseptic power as some phenolic substances do (it does not coagulate albumen). Emmerich administered 0·25 gramme subcutaneously to guinea pigs, without prejudicial results. "A 1 per cent. solution is sufficient for antiseptic dressings."

"Loretin," meta-iodo-oxy-quinoline sulphonic acid, $C_9H_4I(OH)N.HSO_3$, lately introduced as another substitute for iodoform, and reported on by Prof. Schinzinger, of Nuremberg. He showed that its action on granulating and healing processes is a very favourable one, and is superior to that of iodoform, while it is free from objectionable odour, not toxic, and non-irritant, and rapidly removes any

[1] No. 18,913, 1891; *Lembach, Schleicher, and Wolff.*

[2] *Münch. Med. Wochenschr.*, 1890.

eczematous tendency. It is also a good deodorant of purulent secretions and decomposing tissues. "It is very beneficially employed to combat external and parasitic diseases, and as an antiseptic may be blown into cavities for internal affections."

Quinoline when reduced forms a tetrahydride, $C_9H_{11}N$, which is more strongly antiseptic than quinoline.

"THALLINE" is para-methoxy-quinoline tetrahydride, $C_9H_{10}(OCH_3)N$, obtained synthetically by Skraup in 1885. It is an oily liquid, easily frozen, and then only re-melts at 180°, with a strong odour like Tonka beans, and soluble in acids to form crystalline salts. Ferric chloride produces an intense green colour, hence the name (θαλλός, a green twig). The sulphate and tartrate are found in commerce as yellowish-white crystalline powders, soluble in about 7 and 10 parts of water, sparingly in alcohol. They are acid, fragrant, and bitter, and darken in light.

In a paper by H. Schultz "On the Influence of Thalline Salts on Putrefaction and Fermentation,"[1] he states that "0·5 per cent. of thalline sulphate in sterilized gelatine prevented the further putrefaction of meat. Yeast fermentation was considerably retarded by 1 per cent. of thalline tartrate; with a less quantity, however, the activity was increased," probably by supplying nitrogenous food to the fungus. It must be observed that the agent would not answer for a food-preservative, on account of its taste, odour, and physiological action. Thalline was at first extolled as a substitute for quinine, 2 to 8 grains of sulphate or tartrate being given in aqueous solution, but the salts are poisonous to the red blood corpuscles and act on the nerve centres (*Brouardel*). As antiseptics they are still occasionally used for injections (4 to 8 grains to the ounce) in gonorrhœa.

The latest and most important of the derivatives of quinoline, and one that is free from the disadvantage of limited solubility is CHINOSOL.

"By treating oxy-quinoline with alcoholic potassium pyrosulphite, a yellow crystalline powder is obtained, consisting of potassium oxy-quinoline sulphonate C_9H_6 N.O. KSO_3." This product, under the name of "Chinosol" (or

[1] *Centr. Med. Wissensch.*, 1886, p. 113

quinosol) has been patented for use as a disinfectant, and more especially an antiseptic.

As chinosol contains potassium, it differs from diaphtherin by leaving an ash on ignition. It has a slight aromatic odour and an astringent taste; it is easily soluble in water giving a yellow solution which does not stain, has a marked acid reaction, and like oxy-quinoline, gives a green colour with ferric chloride; it is soluble in alcohol. Apart from its germicidal value, the facts that it is non-poisonous, not irritant, and has no objectionable odour, are in favour of its use.

The valuation of a sample can be effected by determining the weight of oxy-quinoline, which it yields on treatment with sodium acetate and subsequent extraction with ether; "this should amount to not less than 50 per cent.,"[1] or, if it were a single sulphur compound, by determining the sulphur, after decomposition, as barium sulphate. In the author's laboratory satisfactory results were obtained by the former process when modified by extracting twice with ether instead of only once, and weighing the total ethereal extract in place of an aliquot portion, as is directed in the original prescription. The yield obtained was 53·4 per cent. of nearly pure oxy-quinoline, resembling the β 4 variety.[2] The nitrogen could not be determined by the ordinary Kjeldahl process, as it was completely volatilized. The potassium was estimated in the same sample of chinosol as potassium sulphate, and found to be 14·4 per cent. K. The theoretical percentages calculated on the anhydrous salt for the formula given above would be 55·1 per cent. oxy-quinoline and 14·8 potassium. On the addition of barium chloride to a solution of chinosol a precipitate of barium sulphate was obtained. This and the acidity would seem to indicate that the substance was an acid sulphate rather than a sulphonate, or that the sample contained free sulphuric acid or acid potassium sulphate, which themselves have considerable antiseptic properties (see page 136). Heated to 100° C., for some hours, beyond evolving at first an odour like oxy-quinoline, no change was apparent; at higher temperatures it blackened.

[1] *J. Pharm. Chim.*, 1896, 3 [10] 495.

[2] Morley and Muir's *Dict. of Chem.*, vol. iii., p. 767.

Dr. Klein has tested samples of chinosol submitted to him with regard to their germicidal value. He employed an agar streak culture of Staph. pyogenes aureus (incubated at 37° C. for two to three days), selecting this organism as the "common microbe of wounds and purulent inflammation," and a gelatine streak culture of B. coli communis (incubated at 20° C. for three to five days), "its power to resist disinfectants being somewhat greater than that of the bacillus of typhoid, and to a considerable degree greater than that of most known non-sporing pathogenic microbes, such as the bacilli of diphtheria, influenza, glanders, swine fever, bubonic plague, and non-sporing anthrax." His method was to infect 3 c.c. of the disinfectant solution in a test-tube from the solid cultures by means of a platinum wire, the organisms being uniformly distributed by shaking. Sub-cultures were taken in suitable media after five minutes. He found that in the case of both Staph. pyogenes aureus and B. coli communis, 1 part in 200 of chinosol succeeded in affecting their subsequent growth, and that 1 part in 50 acted reliably as a germicide. With B. anthracis containing spores, he states that a 1 per cent. solution in five minutes produced sterility. He concludes his report as follows:—

"Comparing these results with those of experiments on the same microbes with pure carbolic acid, the following is to be noted:—A solution of the latter of 1:20 (5 per cent.) strength is required to kill the Staph. aureus or B. coli in five minutes with certainty; 1:33 (3 per cent.) is not reliable in five minutes, whereas chinosol acts germicidally in five minutes on these microbes if used in the strength of 1:150 ($\frac{2}{3}$ per cent.). It has to be added, however, that owing to its unpleasant and obnoxious effects on the skin and wounds a 5 per cent. solution of carbolic acid is scarcely admissible in surgical practice, whereas even a 1 per cent. solution of chinosol is quite harmless.

"Spores of bacillus anthracis can be kept in a 5 to 6 per cent. carbolic acid (absolute phenol) solution for 48 hours without being in the least interfered with in their vitality, whereas chinosol acts germicidally on spores of anthrax in five minutes in solution of 1:100 or 1 per cent.

"These properties, together with its perfect harmlessness

and easy solubility, place chinosol considerably above carbolic acid (absolute phenol) as a disinfectant."

Prof. Emmerich also pronounced chinosol to be far more active than carbolic acid, but states that a solution containing 1 in 40,000 arrests the development of Staph. pyogenes aureus, whereas Dr. Klein's result was that 1 part in 200 is required to affect this organism, or 200 times the quantity. In the author's laboratory B. coli was not sensibly affected after four hours by a solution containing 1 part in 1,000 of chinosol, 1 in 2,000 mercuric chloride producing sterility in less than fifteen minutes under identical conditions.

In comparative experiments made by C. G. Moor, he found that with ten minutes' exposure solutions containing respectively 1 in 5,000 chinosol, 1 in 2,000 mercuric chloride, and 1 in 200 carbolic acid, were required to kill B. typhosus, B. diphtheriæ, B. anthracis (without spores?), and Sp. choleræ, and that only the last three organisms were destroyed by 1 in 200 potassium permanganate. With Staph. pyogenes aureus he required solutions containing 1 in 2,000 chinosol, or 1 in 1,000 mercuric chloride. He concludes that one-tenth of an ounce of chinosol dissolved in three gallons of water (1 in 4800) makes a reliable disinfectant solution.

Beddies and Fischer[1] treated sewage water with (1) 1 in 10,000 chinosol, and (2) 1 in 1000 carbolic acid. In the first test over 99 per cent. of the bacteria were killed, and in the second 77 per cent., after six hours' exposure. They found that 1 in 8000 chinosol killed the bacilli of diphtheria, anthrax, typhoid, and also Staph. pyogenes aureus.

Chattaway and Pearmain report that they succeeded in destroying Sp. choleræ with 1 in 30,000 chinosol, "staphylococcus" with 1 in 20,000, B. erysipelatis with 1 in 15,000, and B. typhosus and diphtheriæ with 1 in 10,000. As a deodorant on putrifying meat the substance gave "exceedingly satisfactory results." Thresh and Sowden[2] state that they found chinosol a reliable disinfectant as a spray of 1 per cent. strength; below this the results were not uniform. Houston did not succeed in killing B. coli in excreta by 1 in 75, and on linen by 1 in 62.[3]

Percy Dunn, in the *Medical Press and Circular*, May 5th,

[1] *Allg. Med. Centr.-Zeit.*, 1897, 47.
[2] *Journ. San. Inst.*, Jan., 1903.
[3] *Practitioner*, Sept., 1902, pp. 331-333.

1895, recommends one part of chinosol with twenty of boric acid as an ideal antiseptic powder for surgical use. He obtained satisfactory results with the use of chinosol in a number of cases of ophthalmia. He also points out that it does not coagulate albumen, and that "it does not injure surgical instruments;" yet from its acid nature it must have a certain deleterious effect on metal, as the proprietors admit in their circular. F. G. Muller reports encouraging results with chinosol in leprosy.[1]

Chinosol has also been incorporated with soap, but as it seems to form an insoluble compound, its germicidal value under these conditions remains doubtful. Experiments made by the author showed that a soap containing 5 per cent. of chinosol was inferior to a 0·5 per cent. mercuric biniodide soap (see Chap. XIII).[2]

Cresochin (F. Fritzsche, *Pharm. Centralhalle,* xxxvii., 247) is stated to be a soluble non-caustic disinfectant composed of "a neutral combination of quinoline-tricresyl-sulphonate and a quinoline compound of tricresol, containing 33 per cent. of quinoline and 17 of cresol." It is recommended for the disinfection of surgical instruments, as it does not darken the steel.

Quinine, $C_{20}H_{24}N_2O_2$, $3H_2O$, appears to be a derivative of a partially hydrogenized di-quinoline, and to have the formula

$$C_9H_6(OCH_3)N-C_9H_{11}(OH)N.CH_3,$$

although it has not yet been synthesized.[3] Its action against fevers is probably as much due to its antiseptic power as to its effect on the nervous system. The natives of Peru were in the habit of purifying the water of fœtid pools by throwing in logs of cinchona (*Humboldt*), but the tannin would also take part in this treatment. Koch observes: "The dose of quinine necessary to destroy the spirilla of relapsing fever would be 12 to 16 grammes, which would kill the host as well as the parasite." A much less dose is sufficient to restrain the spirillum.

[1] *Zeits. oest. Apoth., Ver.,* xxxv., 858.

[2] Also see A. E. Gilles (*Lancet*, May, 1897), S. Giovanni (*Deutsche med. Wochenschrift*, 1897. No. 37,585), E. R. Edwards (*Veterin. Record*, March, 1897), and this volume, *Excreta*, Chap XII.

[3] Liebig's *Annalen*, vol. cciv., p. 90.

Antiseptol, iodo-sulphate of cinchonine, contains 50 per cent. of iodine, and is said by Yvon[1] to be a powerful antiseptic for surgical use. It must not be confounded with other antiseptics having a similar name (see page 250).

A. Raal asserts[2] that strongly fluorescent bodies, such as acridine (p. 253), act as powerful antiseptics in sunlight, while they show but slight action in the dark. Thus a 1 in 20,000 solution of that body was found to kill infusoria, when exposed to sunshine, in 6 minutes, whereas in the dark they resisted its action for 24 hours. Similar results were obtained with quinine sulphate and with eosine. It is inferred that the effect depends on the influence of the fluorescent light rays of the solutions.

Certain faults of many antiseptics and disinfectants in the free state have led to an immense number of attempts to improve them by converting them into various compounds. Beyond the effort to produce new proprietary substances, which has led to a multitude of often misleading titles, many of these preparations have been proved to have utility. The modifications may be generally classified as follows:—

1. *Metallic salts.* Those of the alkalies and earths are generally less active than the free substance. Other metals have been introduced, with the object of adding their special properties, as aluminium for astringency, zinc, copper, silver and mercury for developing microbicidal effect, but it must be remembered that a combination of this kind, though it may have some lateral advantages, is commonly weaker than either agent singly. The same remark applies to the two next groups.

2. *Substituted compounds.* Those with iodine are exceedingly numerous, including a large number which have been improvements on iodoform at the time when it was unduly valued. Where organic radicles, basic like methyl or phenyl, acid like acetyl or benzoyl, are introduced, the physiological properties are usually entirely altered.

3. *Esters* and other substances which, while less poisonous or irritant than the parent bodies, slowly yield the latter by gradual decomposition. Several of these have proved of great value.

[1] *Amer. Journ. of Pharm.*, Oct., 1890.
[2] *Pharm. Zeit.*, 1900, xlv., 569.

CHAPTER X.

ORGANIC SUBSTANCES *(continued)*.

AROMATIC ACIDS AND TERPENES.

BENZOIC ACID: Its use as an Antiseptic—Benzo-boric Acid, &c.—Benzoic Aldehyde, or Oil of Bitter Almonds—Sulpho-benzoic Acid—Benzosol—Benzo-paracresol and Benzo-naphthol. SALICYLIC ACID: Three Isomerides—Salicylates—Oil of Wintergreen—Salol—Salophen—Phenosalyl—Antiseptic Value of Salicylic Acid—Patents—"Lactacidine"—The Use of Salicylic Acid for Preserving Food—Objections—Tablets, Gauze, &c.—Anisic Acid—Cinnamic Acid—Cinnamein—Styracol—Styrone—β-Phenyl-Propionic Acid—Phenyl-Acetic Acid—Gallic Acid—Tannin—Diphenyl Derivatives—Sodium Dithiosalicylate. THYMOL, CAMPHORS, AND ESSENTIAL OILS: The Terpenes, their Properties and Products of Oxidation—Turpentines—Camphors—*Thymol*, Aristol—Menthol—*Oil of Cloves*—Caraway, Hops, &c.—*Terebene*—*Camphor*, Personal Use—Patents—*Eucalyptol*—Myrtol—Terpineol—Absynthol—Borneol—Camphoid—Combining Disinfectants with Soda Crystals—Camphylene—Bases of Powders—The Oxidising Power of Essential Oils—Ozone Test—*Sanitas*, Sanitas Oil—Value of Sanitas as a Disinfectant—Pinol—Peroxols.

BENZOIC ACID GROUP.

BENZOIC ACID, $C_6H_5 . CO . OH$, exists in gum benzoin, balsams of Peru and Tolu, and several aromatic gums that have been used for ages for embalming. It melts at 121° C., boils at 250° C., but sublimes slowly with a pungent, aromatic odour, even at ordinary temperatures. It is soluble in about 400 parts of cold water, yielding an acid solution of pungent, disagreeable taste. It acts as a stimulant, expectorant, diuretic, and is strongly antiseptic both as solid, solution, and vapour, and even in its salts, which have little odour or taste, and as regards the alkaline ones are easily soluble.

Salkowski,[1] in a number of experiments with meat juice inoculated with putrid fluid, showed that benzoic acid, in a dose smaller than salicylic, prevented for a long time the putrefaction of the mixture and the development of bacteria. Bucholtz[2] found that 1 in 1,000 stopped the growth of micro-

[1] *Ueber die antisept. Wirkung d Salicylsäure und Benzoesäure, Berlin Klin Wochenschr.*, 1875, p. 22.

[2] *Archiv. f. exp. Pathol.*, 1875, vol. iv.

organisms. Haberkorn did not succeed with the bacteria of urine with less than 1 in 400. Jalan de la Croix,[1] in seventy-four experiments with varying quantities, showed that the least quantity that would prevent bacterial growth from being inoculated into a fresh liquid (beef tea) was 1 in 2,800. To kill bacteria he required 1 in 410, and to sterilize spores 1 in 50. As regards non-organized ferments ("enzymes"), Wernitz[2] declares that pepsin is neutralized by 1 in 200, and others by 1 in 300, of benzoic acid or benzoate of soda.

Graham Brown[3] stated that sodium benzoate was superior to quinine hydrochloride and sodium salicylate in destroying the virus of diphtheria; he believed even that by saturating the human system with benzoic acid by repeated hypodermic injections, it was rendered almost insusceptible of inoculation with diphtheria.

In disorders of the bladder, attended by ammoniacal urine, Gosselin and Robin[4] proved that benzoic acid taken internally rendered the urine acid, preventing the precipitation of insoluble phosphates, and the formation of carbonate of ammonium and poisonous salts by the urinary bacteria, and also diminished the amount of urea excreted. Therefore, Frerichs introduced it successfully for uræmia. They use 1 to 4 grammes per day dissolved in glycerine and water.

Vallin states[5] that "in most cases, to destroy definitely and without return, germs transplanted from a sterilized liquid into the midst of an appropriate culture fluid, the proportion of benzoic acid should be 1 in 77, or even 1 in 50." This would make it rather more potent than phenol, cresol, or other similar compounds. It is not poisonous; Prof. Senator, of Berlin, gave as much as 50 grms. of sodium benzoate a day to a patient with acute rheumatism, without ill effect. As much as 1 oz. of ammonium benzoate per day can be taken without any noticeable effect, and is excreted as hippuric acid in the urine.

In those cases in which the odour and taste is immaterial, a saturated solution of benzoic acid in water delays the

[1] *Archiv. f. exp. Pathol.*, 1881, vol. xiii., p. 175.
[2] Dorpat Essay, 1880.
[3] Kleb's *Archiv.*, vol. viii., p. 140.
[4] *Arch. générales de Méd.*, 1874, vol. xxiv., p. 566.
[5] *Désinfectants*, p. 202.

putrefaction of animal matters much more effectively than salicylic. It has less effect on vegetable effusions. It is also useful for preventing fats from becoming rancid, as in "adeps benzoatus," benzoated lard of many Pharmacopœias. Added to milk, a very small quantity prevents coagulation.[1] In a series of experiments by the author in 1899, in which molecular proportions, *i.e.*, sodium benzoate ·026, potassium benzoate ·029, benzoic acid ·022, per cent., were separately mixed with milk, it was found that all had a marked action in retarding the souring, that the free acid was the most energetic, but that the effect came to an end sooner than with inorganic salts such as fluorides, probably owing to the benzoic acid being itself decomposed by some of the organisms.

Benzoic acid and benzoates are ingredients in many antiseptic mixtures. Patented preservative mixtures containing benzoic acid are numerous. With regard to complex formulas it may generally be said that the additions are made for the purposes of solubility or disguise, or to institute a special preparation, and that they very rarely increase, and often seriously diminish, the activity of the central ingredient, which is preferably used only dissolved in water, as pure as possible, and in defined strength.

Dr. Miller states that by using the following mixture he could completely sterilize the mouth and cavities in carious teeth :—"Thymol, 4 grains; benzoic acid, 45 grains; tincture of eucalyptus, 3½ drachms; water, 25 ozs."[2] Benzoic gauze contains 4 per cent. of benzoic acid.

By heating benzoic with boric, tartaric, or citric acid, double compound acids called benzo-boric, etc., are formed, which are, of course, antiseptic, and are mentioned in some of the older patents. Although the benzoic acid is thus rendered much more soluble, and its taste is in great part disguised, it frequently crystallizes out, and hence these compounds are now seldom heard of. This separation also makes them irritant to wounds and mucous surfaces.

Benzoic aldehyde, or benzaldehyd, $C_6H_5 . CO . H$, occurs with hydrocyanic acid in oil of bitter almonds. Angus

[1] *Chem. News*, 1886, i., 130; Horn, *Zeitschr. f. Chem. Industr.*, vol. ii., p. 329, 1888.

[2] *Chem. and Drug.*, 1887, p. 83.

Smith[1] considered it a little below phenol in antiseptic power. It readily oxidizes to benzoic acid, is sparingly soluble (1 in 30), and is of no hygienic use except in ointments, when the crude oil is very effective against eczema, irritation, and parasites, partly on account of the prussic acid it contains. Obviously the skin must not be broken.

SULPHOBENZOIC ACIDS, $C_6H_4(HSO_3)(CO.OH)$, of which there are three isomers, made by the action of oil of vitriol on benzoic acid, are very soluble, and have an acid and bitter taste. They and their salts are antiseptic. The mixture of sodium salts is met with as an antiseptic under the name of SODIUM SULPHOBENZOATE.[2] The derivative "SACCHARIN," "gluside," or benzoyl-sulphonimide, has also a preservative power, and has been given internally to stop decomposition of urine in chronic cystitis.[3] It has the constitution, $C_6H_4\langle^{SO_2}_{CO}\rangle NH$. The commercial article, used for sweetening, is an impure sodium salt. Von Heyden proposes as a substitute, *Amidobenzosulphon-imide* $C_6H_3(NH_2)\langle^{SO_2}_{CO}\rangle NH$, which "with a sterilizing action equal to that of saccharin, is only half as sweet, without unpleasant after-taste. The sodium salt is not antiseptic."[4]

BENZANILIDE is a weak antiseptic used as an antifebrile.

"BENZOSOL," or benzoyl-guaiacol $(C_6H_5)CO.O(C_6H_4.OCH_3)$, is a crystalline powder, colourless, almost free from taste and smell, insoluble in water, easily soluble in alcohol, and melts at 50° C. It is said to combine the effects of guaiacol and benzoic acid without any disadvantages, and to be very useful in tuberculosis, facilitating expectoration and rendering the sputum free from bacilli. Prof. Sahli, however, remarks that the commercial article is of varying composition, that he found some specimens inert, and that "as the effect of guaiacol and creosote were due to local antiseptic action in the stomach, benzosol could not take their place." It is used largely in diabetes mellitus.

BENZO-PARACRESOL, $C_6H_3(C_6H_5.CO)(CH_3).OH$, is an antiseptic prepared by the action of sodium benzoate on paracresol

[1] *Disinfectants*, Edinburgh, 1869.
[2] *Journ. Soc. Chem. Ind.*, 1888, p. 226.
[3] *Lancet*, 1888, i., 1195.
[4] Patent 12,743, 1895.

in presence of oxychloride of phosphorus. It occurs as a crystalline powder almost insoluble in water, but soluble in alcohol (0·15 per cent.). It melts at 71° C.[1]

Benzo-naphthol, $C_{10}H_7O.CO(C_6H_5)$, from β-naphthol, melts at 110° C., and has also been proposed for internal antisepsis.

Salicylic Acid.

There are three isomeric oxybenzoic acids, of which only the ortho-compound, called salicylic acid, $C_6H_4(OH).COOH$, is of practical importance. It is met with in minute white needles or prisms, of pungent odour and sweet taste (inodorous when pure, *Charteris*), soluble in about 500 parts of cold, and 15 of boiling water, in 7 of alcohol, 3 of ether, and 50 of glycerine. When heated quickly it breaks up into phenol, which distils, and carbonic acid. The same decomposition occurs in the human system, as phenol appears in the urine. It is antiseptic and antipyretic.

J. B. Duggan found that it was twice as powerful an antiseptic as the corresponding para-oxy-benzoic acid, whilst the meta-acid had intermediate properties.[2]

"Artificial" salicylic acid (from sodium phenate and carbonic acid) is somewhat more toxic in its action than the pure "natural" acid obtained from oil of wintergreen. This is due to two foreign acids, isolated by Williams in 1878, and found by Dunstan and Bloch[3] to be ortho- and meta-cresotic acids, $C_6H_3(CH_3)(OH).COOH$, derived from the cresols contained in the crude phenol from which the salicylic acid had been prepared. Schering and others now prepare a pure artificial acid from pure phenol, which acts in the same way as the natural acid. Salicylic acid melts at 156·7° C. It gives a purple colour with ferric salts, therefore cannot be prescribed with them. It is not corrosive, does not coagulate albumen, and is not volatile at ordinary temperatures.

The salicylates are much more soluble. Salts of nearly every metal have been prepared and recommended for various uses; but sodium salicylate, $C_6H_4(OH).COONa$, is the most usual one.

[1] *Revue de Chim. Industr.*, April 15, 1893.
[2] *Am. Chem. Journ.*, vol. vii , p. 62.
[3] *Journ. Chem. Soc.*, April, 1891.

Oil of Wintergreen (*Gaultheria procumbens*), and Oil of Sweet Birch (*Betula lenta*) are almost entirely methyl salicylate, $C_6H_4(OH)COO(CH_3)$. It is a colourless, fragrant liquid, sparingly soluble in water, but easily in alcohol, and also in alkalies. Specific gravity, 1·18; boiling point, 222° C.

Perier, of the hospital of St. Antoine, Paris, substituted the former oil for phenol in surgery, using a mixture which was perfectly miscible with water:—Oil of Wintergreen 30 grammes, tincture of quillaia 6 grammes, water 1 litre. Gosselin and Bergeron[1] found that this oil, both as a solution and as vapour, hindered the putrefaction of blood, and that the odour was inoffensive. It is still used in France for dressings, but is inferior to phenol and other agents in power. It does not coagulate albumen, and is comparatively non-poisonous, but it is found that the natural oil is somewhat irritant, whereas pure methyl salicylate is not so.[2]

"Salol," Phenyl salicylate, $C_6H_4(OH).COO(C_6H_5)$, introduced in 1886, is a white crystalline powder, melting at 42° C., with a faint aromatic odour, practically tasteless, neutral, insolubie in cold water, soluble in 15 parts of rectified spirit, in 3 of ether, and very soluble in chloroform and in oils. Antipyretic and antiseptic, it passes through the stomach unchanged, to be decomposed in the duodenum into phenol and salicylic acid.[3] It is used in diarrhœa, dysentery, cholera, etc., as an internal antiseptic, also as an injection in gonorrhœa and cystitis. It has been employed externally as a substitute for iodoform in skin and nasal diseases. Löwenthal[4] has shown that salol will kill cholera bacilli in a paste containing pancreatic juice. Spirituous solutions (5 per cent.) are employed with various flavouring agents for mouth-washes and dentifrices, toilet-powders, and soaps. When melted with camphor, salol, like many other substances, forms a permanent liquid which has also been used to replace iodoform.[5]

"Salophen," $C_6H_4(OH)(COO.C_6H_4.NH.CO.CH_3)$, the salicylic ester of acetyl-para-imidophenol, resembles the

[1] *Arch. général. de Méd.*, 1881, p. 16.
[2] *Lancet*, 1898, i, 52.
[3] *Brit. Med. Journ.*, 1887, vol. xi., p. 1438.
[4] *Comptes rendus*, vol. cvii., p. 1169.
[5] *Répertoire*, 1889, p. 185

preceding in properties, but is said to have rather stronger antiseptic power. M.P. 188° C. It has not been much used, and is expensive.

Cresyl Salicylates.—The three cresols form corresponding salicylates, and have been proposed as internal antiseptics. Betol, salinaphthol, or naphthosalol, is a β-naphthol salicylate, and has already been described under Naphthol (p. 242). Salbromanilide is said to be a mixture of bromacetanilide and salicylanilide. Salipyrin is a compound of antipyrin and salicylic acid (p. 252).

Phenosalyl is a mixture of phenol, salicylic, benzoic, and lactic acids, made by heating them together at 140° C., adding menthol and eucalyptol, and, after cooling, adding four times the volume of glycerine. According to Sibut, it is composed of phenol 80, salicylic acid 10, lactic acid 20, menthol 1, melted together.[1] It is a clear, syrupy liquid, of sweetish taste, easily miscible with water or alcohol, is not poisonous, and has a pleasant and non-persistent odour, which does not cling about the hands and clothes. The solutions have no corrosive action on the skin, the mucous surfaces remain smooth and slippery, and do not become dried up, as is the case after washing with carbolic acid or corrosive sublimate. Of course, this latter advantage belongs to the glycerine, and would equally pertain to phenol or mercuric chloride in the same medium.

Prof. Fränkel,[2] in a series of bacteriological trials, found that phenosalyl possessed an antiseptic power superior to phenol in dealing with the micro-organisms of cholera, anthrax, pneumonia, typhus, diphtheria, tuberculosis, *Bacillus pyocyaneus*, and *Staphylococcus pyogenes aureus*. It has been used by Duloroy in the sterilization of instruments, of gauze, and of different organic substances like blood, as well as decomposing urine and the saliva of consumptives with most encouraging results. It does not corrode nor discolour metals under ordinary circumstances of contact.

This is an example of a mixture which seems to present great advantages. Of late years there has been a tendency to use complicated compounds, most of them only soluble in alcohol, which, apart from expense and other faults, is

[1] *Year B. Pharmacy*, 1899, 234.

[2] *Bacterienkunde*, Berlin, 1890.

inadmissible as a medium for many purposes. The name is rather an unfortunate one, as leading to a wrong idea of its composition.

Salicylic acid is by no means an innocent remedy. In fact it can be a powerful poison, as it has a disintegrating action on the blood corpuscles. The salts cause albuminuria, hence, must be irritating to the kidneys, probably through phenol being formed.[1] The acid, in strong (alcoholic) solutions, or in ointments, is so caustic that it is the basis of most of the popular cures for corns.[2] The official dose of the acid is 5 to 30 grains. Dr. Bond stated that he had taken 10 grains daily for a month without bad effect, but Dr. Brouardel has noticed daily doses of 2 grammes to produce grave symptoms of intoxication and poisoning. Kolbe[3] first drew attention to the antiseptic properties of salicylic acid. He showed that it prevented the action of enzymes (unorganized ferments), like diastase, emulsin, and that of mustard, also gastric digestion, fermentation by yeast, ammoniacal fermentation of urine, and the germination of seeds. In the body it undergoes a change into phenol and carbonic acid (a reverse to that in its preparation), as phenol appears in the urine. F. D. Simons, and also Chittenden, found that salicylic acid and salicylate of soda greatly retard peptic digestion, and H. Leffmann[4] after a number of experiments concluded that "salicylic acid in all its forms, natural, crude commercial, and refined, is distinctly antagonistic to most enzymes, especially those that convert starch." Leffmann and Beam had shown[5] that salicylic acid, 1 in 20,000 retarded the conversion of starch in the proportion of 245 to 174, or 29 per cent., while 1 in 1,000 entirely prevented it, both with diastase and pancreatic ferment. H. A. Weber came to similar conclusions.[6]

The strength required for killing bacteria has been variously given by different observers. As not more than about 1 in 500 dissolves in *cold* water, the higher strengths given below are impossible without the use of heat, alcohol

[1] *Lancet*, Dec. 20, 1879.
[2] Whelpley, *Chem. and Drug.*, Aug. 16, 1890.
[3] *J. für Prakt. Chem.*, 1874, vol. x., p. 89.
[4] Franklin Institute, Dec. 20th, 1898.
[5] *Analyst*, 1888, 103.
[6] *Journ. of Amer. Chem. Soc.*, 1892, p. 4.

or a base. Ratimoff[1] used 1 in 400, practically a saturated solution in water and a little spirit; Jalan de la Croix,[2] 1 in 200 for milk, and more than 1 in 35 for germs in meat juice; Bucholtz,[3] 1 in 362; and Kühn, 1 in 200 for germs in albumen solution. As to salicylate of soda, the necessary dose is stated as 1 in 100 by Miquel, and 1 in 161 by Bucholtz.

Vallin[4] points out that "this action on ferments and microbes is often only temporary; the ferments and bacteria rapidly become used to their new surroundings, and the generations that succeed resist doses that had been fatal to their ancestors, and the work of fermentation goes on again at the end of a few days. Neubauer and Béchamp have specially proved this curious phenomenon of the habituation of ferments to progressive doses of phenol and salicylic acid. It follows that, to obtain a durable antiseptic effect, we must at frequent intervals add new and increasing doses of the agent. For this reason, in alcoholic beverages which can only be preserved by the aid of salicylic acid, the dose of this substance sometimes reaches as much as 1·5 grammes per litre. Even then experience has shown that poor wines and ciders soon undergo fresh fermentation of acid or putrid character. Salicylic acid, then, is a convenient antiseptic, but it gives no absolute guarantee, and its power is limited." In experiments a few years ago at the Kansas University on the preservation of cider, it was found that at least 1 of the acid in 1000 is needed to prevent souring, and that calcium sulphite is more efficacious.

The very sparing solubility of salicylic acid in water has led to a variety of devices for increasing it. Alcohol is in many cases unsuitable; glycerine only dissolves 2 per cent.: alkalies form salicylates, which, although soluble, have only about one-third the antiseptic power of the free acid. Borax solution dissolves a large quantity of salicylic acid, forming a loosely-combined crystalline compound, inodorous, neutral, and of little taste, called borosalicylate of soda. It is much more soluble, and is more antiseptic than either of its components (see under *Boric Acid*, p. 143).

[1] *Bied. Centralblatt*, vol. xiv., p. 360.
[2] *Arch. exp. Pathol.*, 1881.
[3] *Ibid.*, 1875.
[4] *Désinfectants*, p. 182.

The addition of a mixture of salicylic and boric acids and borax to flour, to prevent secondary fermentation of the dough, has been patented.[1]

LACTACIDINE solution contains 2·65 per cent. lactic acid, and 0·35 per cent. salicylic acid, "to which other materials, such as sugar or glycerine, may be added." It is used for preserving articles of food—*e.g.*, butter. It may be removed by washing before use.[2]

Salicylic acid has been largely used for preserving perishable foods, in the proportion of 4 to 8 grains to the pint or lb., for preventing fermentation in saccharine liquids and for keeping jams. "As a preservative it is best applied in process of preparation. It is advisable to gradually introduce it in the solid state into the boiling mass" (but it somewhat readily volatilizes with the vapour of water), "constantly stirring, or the acid may be rubbed down with the fruit juice, and then added. In any case the finished product ought not to show any white flocks." Another mode is to cover the cold uncooked fruit with the cold salicylated juice of the same fruit, made by pressing, adding to every pound of juice 15 grains of the acid, heating, and allowing to cool. In this way, cherries, plums, etc., can be preserved all the winter uncooked, and almost all the salicylic acid can be removed by washing the fruit before cooking.

Many preparations, more particularly of salicylic and boric acids, are sold as "lard bleachers," and "fruit, wine, and cider preservatives:" most of them are needlessly complex, and some specially objectionable from the flavouring and colouring ingredients introduced. A patent of 1893 describes a mixture of boric acid, sodium salicylate and potassium bicarbonate which has been allowed to absorb sulphur dioxide from the fumes of burning sulphur, "with or without the addition of capsicum and primrose yellow." Ferrous salicylate has been proposed for preserving eggs.[3] Most authorities agree that salicylic preservatives are most objectionable, especially in milk for young children. Powdered salicylic acid, that has been used for hams, fish, etc., is mostly washed off, but when mixed with,

[1] Patent No. 16,502, 1887.
[2] *Grosfils*, Patent No. 2,235, 1887.
[3] Patent 18,130 of 1898.

or allowed to penetrate the food, chronic dyspepsia and other symptoms would certainly be caused by the relatively large quantities that would accumulate in the system. There seems evidence to show that, like lead and arsenic, it has a cumulative action. Brouardel[1] specially characterizes salicylic acid as being injurious in cases of weak or diseased kidneys by its accumulation in the system. Vallin,[2] in an exhaustive discussion on this point, shows that if a man consumes an average quantity of salicylated foods and drinks as met with in France (he gives tables of the amount customarily added to a number of foods) he would absorb per day 3 grammes of salicylic acid. He observes that it is nefariously used to secure the disposal of inferior articles that would not otherwise be saleable. In 1880 the French Committee of Public Hygiene, after the matter had been fully reported upon by M. Dubrisay, passed, on February 7th, 1881, the following edict which is still in force :—

"*Est interdite la vente de toute substance alimentaire, liquide ou solide, contenant une quantité quelconque d'acide salicylique ou d'un de ses derivés.*"

The English Departmental Committee in 1901 recommended that this acid should not be used in a greater proportion than 1 gr. per pint in liquid food and 1 gr. per pound in solid food. Its presence in all cases to be declared.

K. Portele says[3] that salicylic acid cannot be considered a success as a preservative either for butter or milk, as it gives to them an unpleasant sweetish odour, which increases until decomposition takes place.

H. A. Weber[4] and Dr. H. Vogel[5] strongly condemn the practice of adding this preservative to food. Nessler observes that "salicylic acid is not a natural constituent of any food, and its addition is a fraud on the quality." He, with Vogel, Pasteur, and others, demanded that the addition of any quantity of this acid to wine should be mentioned on the bottle. The German Government seem to be yet undecided.

In England, although a few trifling increases of fine have followed the finding of salicylic acid by public analysts in

[1] "Intoxication par Produits journellement absorbés à petite dose," *Internat. Hyg. Congress*, Geneva, 1882, ii., 352.

[2] *Désinfectants*, pp. 189 to 193.

[3] *Landw. Versuchs. Stat.*, vol. xxvii., p. 143.

[4] *Journ. Amer. Chem. Soc.*, vol. xiv., pp. 4 to 14.

[5] *Deutsche Viert. f. öff. Ges.*, 1880, p. 402.

milk where there was added water also, it seems to be recognized as a customary addition to syrups and to "British wines." If wines, however, be carefully made, they can be sterilized without any drug, and will keep for a reasonable time after opening.

Minute traces of salicylic acid are present in fruits, especially in strawberries, probably as methyl salicylate.[1]

In Austria-Hungary salicylic acid is forbidden in milk, but in the Netherlands it is largely used for beer, wines, fruit juices, fruit jelly and lemonade. In the United States its effect is being specially studied by Dr. Wiley for the Board of Agriculture.

Among special salicylic acid preparations the following may be noticed:—

Solution for Local Antisepsis.[2]—Water, 1,000; boric acid, 12; salicylic acid, 2.

In Patent No. 15,564, 1887, Boake and others show that "sodium sulphite dissolves one-sixth of its weight of salicylic acid"; they propose to make such solutions with any alkaline sulphites or bisulphites for antiseptic purposes.

"Strock's Antiseptic Paper."—See p. 143.

Antiseptic Tablets.—"(1) For Thiersch's solution: 14 grains of 'resublimed' salicylic acid and 84 grains of pure boric acid, compressed into a tablet, are dissolved, when required, in 16 ounces of hot distilled water.[3] (2) Pastilles of sodium bicarbonate, biborate, benzoate, and salicylate, with menthol, eucalyptol, and oil of wintergreen. One of the pastilles gives 2 ounces of a solution to be applied as spray in nasal catarrh." "Strongly deodorant as well as antiseptic."[4]

Salicylated Gauze.— Gauze washed with soda to remove grease, then in succession with water and acidulated water, then bleached by chloride of lime and weak acid, and finally well washed with water and dried. Next soaked in a solution of salicylic acid, 5·6 parts; glycerine, 15; rectified spirit, 50; distilled water up to 100 parts; drained, nearly dried by a current of sterilized warm air, rolled or folded by machines

[1] See *Journ. Amer. Chem Soc.*, xxv., 242; *Zeit. Nahr. u. Genusmittel*, 1903, vi., 447
[2] Carcano and Cesares, *Revue de Chim Indust.*, April 15th, 1893.
[3] *Chem. and Drug.*, vol. xxxviii., 1891.
[4] *Lancet*, 1890, ii., 1889, ii., 174.

previously made aseptic. The finished gauze is packed in cylinders freshly lined with melted paraffin sterilized by heat. The gauze is thus kept permanently slightly moist.[1] Contact with iron must be avoided, or purple stains result.

A very large number of derivatives of salicylic acid have been introduced, and many of them patented, as antiseptics in medicine, as for instance F. Hoffmann's sodium ethyl-salicylcarboxylate[2]; Eichengrün's "Resaldol," an acetyl condensation product with resorcinol, said to be toxic to bacteria, not only in neutral but in alkaline menstrua (he also recommends the similar product from thymol).

Anisic Acid or para-oxymethyl-benzoic, $C_6H_4(OCH_3)COOH$, occurs in colourless prisms, melting at 175° and distilling at 280° C. The sodium salt was recommended by Curci, in 1887, as antiseptic and antipyretic, in doses of 15 grains. It was said to be analogous in action to sodium salicylate, but without disturbing influence on digestion.

Cinnamic Acid, $C_6H_5.CH:CH.COOH$, also met with in prisms, is more soluble; melts at 133°, boils at 290° C. It is somewhat strongly antiseptic. Balsam of Peru contains cinnamic and benzoic acids. Piorkowski[3] finds that proportions of the balsam up to 20 per cent. have only a slight retarding action on the growth of bacteria. A culture of B. pyocyaneus after contact with it for 24 hours still showed some growth when transferred to a nutritive medium. Cinnamein (benzyl-cinnamic ester, of which the balsam contains about 62 per cent.) does not destroy bacteria at a concentration of 1·5 per cent., nor does styracin at 4 per cent. Cinnamic acid at 2 per cent. prevents the growth of bacteria, and at 4 per cent. destroys them. Peru and Storax balsams are parasiticide in skin diseases.

Styracol or cinnamyl-guaiacol, $C_6H_5.CH:CH.COO(C_6H_4.OCH_3)$, occurs in needle crystals; is said to be a strong antiseptic in catarrh of the bladder and intestines, and in phthisis; soluble in alcohol.[4]

Styrone, cinnamic alcohol, forms silky white crystals of a sweet taste, and having an odour like hyacinths. It is

[1] Seward Williams, *Chem. and Drug.*, May 27, 1893.
[2] *Chem. Zeit.*, 1901, xxxv., 1045.
[3] *Chem. Centralblatt*, 1903, i. [7], 414.
[4] A. Haas, *Sudd. Apoth. Zeit.*, 1891, p. 55.

soluble in 12 parts of water, and easily in alcohol. The saturated aqueous solution has been recently used in America for the deodorization of foul ulcerated surfaces, and it does not cause irritation. As an antiseptic it is said to exceed thymol. This explains the healing properties long attributed to tincture of benzoin, of which liquid storax is a constituent.

β-Phenyl-propionic Acid or hydrocinnamic acid, $C_6H_5.CH_2.CH_2.COOH$, is formed in the decay of albuminous matter, and, like other similar products, is a bactericide. It forms fine needles, moderately soluble, melting at 47° and boiling at 280° C. Klein regards this and phenyl-acetic acid, $C_6H_5.CH_2.COOH$ (sparingly soluble pearly plates, melting at 76°, boiling at 262°, strong odour of burning urine), as among the strongest of disinfectants. Laws has studied the next acid in this series (see p. 213).

Gallic Acid, trioxybenzoic, $C_6H_2(OH)_3,COOH$, is astringent and feebly antiseptic. It occurs in sparingly soluble inodorous needles.

Tannin, gallotannic acid, $C_{14}H_{10}O_9,2H_2O$, is an amorphous powder, usually brownish, very soluble, and strongly astringent. It is well known to precipitate gelatine, and to form a compound with skins which is imputrescible (leather). It also coagulates albumen. Therefore it is, in some sense, antiseptic, but Goselin and Bergeron,[1] having added to 2 grammes of fresh blood 8 drops of a 10 per cent. aqueous solution of tannin, saw vibrios appear in the mixture on the fourth or fifth day—that is to say, almost as soon as they would without any antiseptic. Gubler and Bordier[2] state that a horse which for many days had received doses of 20 grammes of tannin, remained with its blood unputrefied till the fifth day after death.

None of the extracts of the many varieties of tannins from different plants have even the power to preserve their own solutions.

Sodium Dithiosalicylate "No. 1," $\begin{matrix} S.C_6H_3(OH).COOH \\ | \\ S.C_6H_3(OH).COOH \end{matrix}$ is said to be a powerful antiseptic. According to Hueppe,

[1] *Arch. de Méd.*, 1881, p. 16.

[2] *Bull. de Thérapeut.*, 1873, vol. lxxxiv., p. 265.

in a 15 per cent. solution the most resistant bacilli are easily destroyed in from twelve to fifteen minutes. In a severe case of ozæna it effected a complete cure in a relatively short time. In $2\frac{1}{2}$ to 5 per cent. solution this preparation is reported to have yielded most strikingly beneficial results in the treatment of foot-and-mouth disease.[1]

Thymol, Camphors, and Essential Oils.

From the time of the ancients it has been known that this class of aromatic bodies had a prophylactic action against fevers, against insects, and against offensive odours in air. The precious woods were those which contained essential oils, like sandal-wood and cedar; they were used in constructions wished to be imperishable, and for boxes to contain valuable tissues and documents. They were burnt for fumigations to drive away diseases, they were carried about the person, they were thrown as logs into water, and mixed in wines and possets. The ancient classic wines had generally a strong resinous flavour, due to the admixture of herbs, and even to a trace of wood-tar purposely added to the grapes to check objectionable fermentation, also to bitumen on the stoppers. Apart from the agreeable odour, there was also (p. 288) some sanitary use in perfumes.

A large number of patents for disinfection contain aromatic gums and resins as adjuncts. It is well known that such were used with bitumen for embalming, and bodies have been preserved in this way. The result, however, was in great part due to dessication and protection from the air.

Musk, which seemed to give some relief in plague cases at Hong Kong, has been successfully used in large doses for cholera by Monsiorski.[2]

These odorous principles may be divided into two classes:

Class I.—Hydrocarbons, composed of carbon and hydrogen only. They mostly belong to the terpene group, $C_{10}H_{16}$, or derivatives of it. This formula includes the liquid portions of the oils of thyme, orange, lemon, savine, turpentine, juniper, hop, cloves, camomile, and the majority of others.

[1] Helbing, *Mod. Materia Medica*, 1895, p. 57.

[2] *Prov. Med. Journ.*, Feb., 1894.

It will be noticed that the use of condiments may be explained on the assumption that they are all (including salt, mustard, and vinegar) antiseptic and preventive of fermentation, hence germs in the alimentary canal have their action arrested. Oils of capivi and cubebs, probably affecting micro-organisms in the urinary tract, have the polymeric formula, $C_{15}H_{24}$, as proved by their vapour density. Cedrene, from cedar, is said to be $C_{16}H_{26}$, hence would not be a terpene. Menthene from peppermint is $C_{10}H_{18}$. The cause of the differences in odour of these different compounds of the same formula is not yet entirely known, but in many cases the difference is due to physical isomerism. All are liquids with boiling points much higher than that of water (mostly 160° to 180° C.), yet they emit at ordinary temperatures minute quantities of strongly scented vapour, and are readily volatilized with steam. Their specific gravity is usually less than that of water (0·83, orange, to 0·94 caraway), and they are almost insoluble in it; they are readily soluble in alcohol, forming "essences," and in other hydrocarbons and in fatty oils. When fragrant plants are distilled with water the essential oils float on the surface of the distillate, while a small proportion dissolves to form the "distilled waters" of pharmacy, all of which are mildly antiseptic.

Both the essential and the fatty oils produce a greasy spot on paper, but the spot produced by the former gradually disappears, whereas that of the latter remains fixed, so that the presence of adulteration can be easily detected.

The essential oils neither combine with, nor dissolve in, alkalies; yet, if they be present when resins or fat are saponified, a large proportion remains dissolved in the soap, and is only liberated on dilution with water, when an emulsion similar to those obtained with tar oils is formed.

Chlorine, bromine, and iodine act on most of the essential oils (iodine at first merely dissolves), giving compounds in which the halogen displaces one or more atoms of hydrogen, at the same time the odour is much affected, becoming gradually pungent. Excess of chlorine breaks them up entirely into hydrochloric acid and carbon. Therefore they are not suitable for use with the halogens. The antiseptic or disinfectant properties of substituted essential oils are not well known, but there is no evidence to indicate their utility.

The terpenes rapidly absorb dry hydrochloric acid gas, yielding compounds called artificial camphors; some of them are crystalline, and in appearance and properties much resemble natural camphors. Patents have been taken out for these products, but they have not hitherto been of much value. The artificial camphor obtained from oil of turpentine is the best known. Artificial camphors of a different kind are formed from the terpenes by slow combination with water.

Turpentines.—When an incision is made in a pine tree, a resinous fluid flows out, which is mainly a solution of various resins in the hydrocarbon, $C_{10}H_{16}$, called "oil or essence of turpentine." "Common turpentine" comes chiefly from *Pinus abies*, "Venice turpentine" and "Bordeaux turpentine" from *Pinus maritima*, and "Chian turpentine" from *Pistacia lentiscus*. They are somewhat different in antiseptic value, but different specimens vary among themselves.

By distillation with water, about one-fourth (the essence) passes over with the steam, while three-fourths remain behind as rosin. The latter has no antiseptic power, but is used as an adjunct or medium in a large number of organic disinfectants (Jeyes, etc.).

"Camphine" is the oil of turpentine from *Pinus australis*. Letheby found that 1 in 4,000 of oil of turpentine in air prevented necrosis.

Class II.—Oxidized Compounds, such as camphor, thymol, etc., are crystalline solids, existing dissolved in the natural oil, from which they either separate spontaneously or by refrigeration. They were formerly called *stearoptenes*. Some of them have been formed by oxidation of the hydrocarbons, others are of a different constitution, such as:—

Thymol, propyl-methyl-phenol, or propyl-metacresol, $C_6H_3(CH_3)(C_3H_7)OH$. By cooling oil of thyme, crystals of thymol separate, while the liquid portion consists of thymene, $C_{10}H_{16}$, boiling at 165° C. Oil of thyme contains about equal proportions of thymol and thymene; both have the pleasant odour of the plant and a hot aromatic taste.

Thymol is easily fusible (melting point, 44° C.), lighter than water, in which it is very sparingly soluble (3 parts in 1,000), and is easily soluble in alcohol. It does not readily

combine with, or dissolve in, alkalies, and is insoluble in acids except sulphuric, with which it unites to form thymol-sulphonic acid, in almost inodorous soluble crystals whose physiological properties do not seem to have been examined.

Dr. Paquet first[1] recommended thymol as an antiseptic in surgical dressings, and as an inhalation in pulmonary gangrene. Jalan de la Croix[2] found on an average that while 1 in 1,000 prevented bacteria from growing, 1 in 100 was necessary to kill them, and as much as 1 in 20 to destroy the spores. Miquel ranks it as strongly antiseptic, since 2 grammes "neutralized" a litre of beef tea. Other observers found the following strengths necessary to prevent the development of bacteria; in urine, 1 in 3,000 (*Haberkorn*); in infusion of peas, 1 in 3,027 (*Kuhn*); in tobacco infusion, 1 in 2,000 (*Bucholtz*). Wernitz states that a saturated aqueous solution (3 in 1,000) arrests pancreatic digestion. Kobert, Kohler, and Stern used it to preserve vaccine lymph, as while it prevented it from putrefying, it only slightly diminished its activity. Koch mentions it as specially inhibitory to tubercle. Ratimoff[3] put it fourth in his list of disinfectants, arranged in order of potency (mercuric chloride, silver nitrate, iodine, thymol), saying that "1 in 35,000 killed putrefactive bacteria."

Thymol in a saturated solution in water arrests fermentation and putrefaction better than carbolic or salicylic acids.[4] Thymol gauze is used in surgery, and an ointment has been made with lanoline. It is, however, too expensive for use on the large scale. "Listerine" (p. 142) contains oil of thyme. "Thymocresol" was the name given to a disinfectant made by Ness & Co., Darlington, which was tested by the author in 1899, and found to have considerable activity. Moniodothymol is now patented, along with tri-iodo-metacresol, by Kalle & Co.[5]

Oil of thyme also contains an isomer of thymol, *carvacrol*, an iodine substitution product of which, called "iodocrol," was one of the many rivals of iodoform.[6]

[1] *Bull. général de Thérapeutique*, 1868.
[2] *Archiv. f. experim. Pathol.*, Jan. 20, 1881.
[3] *Biedermann's Centralblatt*, vol. xiv., p. 360.
[4] *Brit. Med. Journ.*, 1875, vol. i., p. 680.
[5] *Analyst*, Feb., 1903, p. 57.
[6] *Pharm. Journ.*, 1896, i., 241; 1898, i., 61.

Aristol or Annidaline, di-iodo-di-thymol, $[C_6HI(CH_3)(C_3H_7)OH]_2$, is a white solid, melting at 60° C., insoluble in water, soluble easily in alcohol and ether. Like most iodine compounds it turns brown on exposure to light and air, liberating iodine. It is said to be strongly antiseptic.

It has been pointed out[1] that thymol and carvacrol, as isomeric forms of methyl-isopropyl-phenol, are typical and well-defined homologues of ordinary phenol. From this it follows that oils of thyme and origanum, as being "liquid preparations containing more than 3 per cent. of carbolic acid homologues," are poisons within the meaning of the new orders (see p. 222), and a similar reasoning would affect a number of pharmaceutical and ordinary remedies of undoubted innocence. Obviously this was not the intention of the legislation.

Menthol.—Oil of peppermint contains a hydrocarbon, menthene, $C_{10}H_{18}$, boiling at 163° C., together with a white crystalline solid obtained by cooling it, menthol, $C_{10}H_{20}O$. Menthol melts at 42° C., and boils at 213° C. It smells of peppermint, and has antiseptic properties.

Peppermint from very early ages has had an immense repute as an arrester of fermentations. Several medical receipts for "plague water" have peppermint as a basis. In a recent cholera scare there was a strong demand both in Germany and England for peppermint herb, and for the oil and water. W. L. Braddon[2] directs attention to the antiseptic properties of oil of peppermint in diseases in which antisepsis is the best mode of treatment. Angus Smith spoke highly of it.[3] Koch stated that 1 part of the oil in 300,000 arrested the development of spores, and that the vapour from warm oil of peppermint quickly killed both spores and bacilli. Dr. A. Macdonald found that the power of menthol is about double that of phenol— "1 in 500 kills bacteria."[4] Both it and oil of thyme seem to be useful antiseptics.

"Mentho-phenol" is a liquid obtained by fusing together 3 parts menthol and 1 of phenol, recommended in the

[1] *Chemist and Druggist*, Aug. 25th, 1900.
[2] *Year Book of Pharmacy*, 1888.
[3] *Disinfectants and Disinfection*, 1869.
[4] *Edin. Med. Journ.*, 1880, p. 121.

strength of 2 per cent. as a surgical, and especially dental, antiseptic.[1]

Oil of Cloves.—This is extensively used for preserving paste, gum, etc., and for carious teeth ("Bunter's Nervine"). It is heavier than most essential oils (specific gravity 1·06), rather more soluble in water, and more volatile (boiling point 143° C.). All these peculiarities increase its value as an antiseptic. It consists chiefly of a phenol called *eugenol* or eugenic acid, $C_{10}H_{12}O_2$, with a liquid terpene $C_{10}H_{16}$, and a variety of camphor called caryophyllin, $C_{10}H_{16}O$.

Oil of Caraway, sp. gr. ·910 to ·920, contains a hydrocarbon carvene, $C_{15}H_{24}$, and an oxidized body carvol, $C_{10}H_{14}O$, isomeric with thymol—specific gravity ·960, boiling point 225° C. The latter yields with an alkaline solution of ammonium sulphide a peculiar substance named carvol hydrosulphide $(C_{10}H_{14}O)_2H_2S$, in yellowish crystals sparingly soluble in alcohol, almost insoluble in water, but slowly decomposed by it. It has an unpleasant odour, and is strongly antiseptic, but hardly available on acount of cost, insolubility, and poisonous character. Jalan de la Croix[2] states that 1 in 1,000 of carvol destroyed the bacteria of tobacco infusion, while 1 in 360 was required for those of urine.

Oil of Cinnamon was considered by Lucas Championnière to be superior to even corrosive sublimate as an antiseptic. Oils of verbena and geranium have similar properties.[3] Oil of garlic, used for phthisis by Dr. Sejournet, of Revin, was called by him "scoradine" when mixed with sterilized olive oil.

Essence of Hops is a powerful agent in checking fermentation, hence its former universal use in brewing. It readily absorbs oxygen, being converted into an acid resinous mass containing valerianic acid, $C_4H_9.COOH$. The main constituents are a terpene, $C_{10}H_{16}$, and valerol, $C_6H_{10}O$.

All the other essential oils are more or less antiseptic, but their general use is negatived by (1) their cost; (2) sparing solubility; (3) their persistent odour, which becomes after a

[1] *Boston Med. Journ.*, cxxxiv., 3.
[2] *Archiv. f. exp. Pathol.*, Jan. 20, 1881.
[3] *Rev. Thérap.*, 1893, p. 290.

time insupportable; (4) their want of energy in terminating, as distinguished from restraining, putrefaction and fermentation changes; (5) internally, their injurious action on digestion. Their chief value, beyond that due to their odours and flavours, consists in their general property of hindering fermentation in the alimentary canal. They are largely used for mouth washes, tooth powders, etc.

Terebene, $C_{10}H_{16}$ (specific gravity, 0·86; boiling point 156° to 180° C.), is a mixture of dipentene and other hydrocarbons, obtained by acting on turpentine with about one-twentieth of its weight of oil of vitriol, and distilling. It is a liquid of strong odour resembling that of thyme and pine-wood, oxidizes less readily than turpentine, and is only slightly soluble in water, but easily in alcohol and oils. Some years ago it was extensively commended as a "disinfectant"; it has now almost fallen out of use except in "Terebene Soap," which is a pleasant preparation of some antiseptic power, containing 1 to 2 per cent. of terebene.

Prof. Maclean, of Netley, reported favourably on its use for surgical and sanitary purposes.

Camphors.—These are oxidized essential oils.

Ordinary or Laurel Camphor, $C_{10}H_{16}O$, is a white solid of specific gravity ·996. About 1 per cent. dissolves in water, communicating to it, as "camphor water," its odour, with its stimulant and antiseptic properties. It is very soluble in alcohol; the tincture in moderate doses is an irritant poison. Dr. Rubini, in Naples, used it largely in cholera and diarrhœa.

Camphor has some repute as a personal prophylactic, but it is obvious that there cannot be sufficient of the vapour to disinfect the air. It is irritant to the skin. It burns with a luminous sooty flame, but when burnt, either alone or with spirit, the products of combustion contain little or no camphor. Spirit lamps containing this and essential oils in spirit have often been proposed for fumigation, but are clearly of no value.

There are numerous inventions relating to camphor. "Sanoscent" is a block disinfectant containing camphor, eucalyptus, pine-oil, "and other germ-killers." The basis of most of the cakes or blocks commonly met with is either naphthalene, paraffin, or plaster. "Hebden's Camphortar" is camphor, eucalyptus, and tar distillates, similarly made

into blocks for lavatories, etc., and also recommended to be grated among clothes for insects (see under *Naphthalene*, p. 199). An "Improved Disinfecting Fluid"[1] consists of 28 lbs. chloride of lime, 14 lbs. of camphor, and 50 gallons of "black varnish" (a coal-tar product) mixed together. "After standing for eight days the resulting substance is ready for use in urinals, etc."

A mixture of equal parts of camphor and animal (vegetable?) charcoal is recommended by Barbocci for preventing the offensive odour and removing the pain (?) of old excavated ulcers.[2]

Camphor forms liquid compounds when triturated with phenol, menthol, thymol or chloral hydrate[3]; the first mentioned was patented by Hille for drains and for dressing vines.[4]

Bromo- and iodo-camphor are strongly antiseptic, but irritant.

Eucalyptol, or eucalyptus camphor, also called *cineol* and *cajeputol*, $C_{10}H_{18}O$, was first isolated by E. Jahns from the essential oil of various species of *Eucalyptus*. Since then it has been detected in numerous other oils. Besides six species of *Eucalyptus* there are 15 plants which yield it. It is a colourless liquid of camphoraceous odour; specific gravity 0·93, boiling point 176° C., and crystallizing point − 1° C. It is practically insoluble in water, but is miscible with alcohol, ether, chloroform, and fatty oils. The *Eucalyptus* trees have long been famous for their anti-malarial action, and are largely planted on the Continent in marshy districts. According to Cloez, the half-dried leaves contain 6 per cent. of the oil. It is used in the antiseptic treatment of atonic ulcers, gangrene, etc., internally and by inhalation for pulmonary affections, and especially for influenza.[5]

Candles containing 5 to 10 per cent. of oil of eucalyptus or cajeput, with or without a little phenol, were patented by

[1] Lees, Patent No. 1738, 1893.

[2] *Chem. and Drug.*, 1887, p. 373.

[3] *Am. Journ. Pharm.*, 1885, p. 429; *Pharm. Journ.*, 3, vol. ix., p. 598.

[4] No. 6,411, 1889.

[5] See Gimbert, *Eucalyptus globulus, and its Importance in Agriculture, Hygiene, and Medicine* (Paris, Delahaye, 1870). Demarquay in 1872 recommended eucalyptol in surgery. Lord Lister has used it as a substitute for carbolic acid.

Wright.[1] In all such fumigating appliances the greater part of the organic matter is destroyed in burning, only a fraction being volatilized unchanged, while the peculiar odour becomes after a time sickly and insupportable. All fumigating candles, except the so-called "sulphur candles" (p. 130) and some bromine and iodine forms (p. 100), are therefore unsatisfactory. Tablets containing eucalyptus oil and chalk, which have a powerful and pleasant odour, have been introduced for domestic use.[2]

Eucalypto-resorcin is a hard amorphous mass obtained by mixing eucalyptol with excess of resorcin in the cold. It crystallizes from chloroform, is insoluble in water, but very soluble in alcohol and in ether. It is said to have some advantages as an antiseptic. Eugol is a liquid containing β-naphthol, boric acid, menthol, thymol, eucalyptol, Gaultheria, and Hamamelis.[3]

Myrtol, from essence of myrtle, is a clear liquid of pleasant odour, boiling between 160° and 180° C. Eichorst recommended it as an internal antiseptic. It is a mixture of dextro-pinene (the main hydrocarbon of turpentine, juniper, eucalyptus, and sage oils, etc.) with eucalyptol, and would be advisedly replaced by the latter (*Jahns*).

Terpin Hydrate, $C_{10}H_{18}(OH)_2,H_2O$, is prepared by the interaction of a mixture of 4 parts of oil of turpentine, 3 parts rectified spirit, and 1 part of nitric acid in shallow porcelain dishes during some days. It occurs in large colourless and inodorous crystals with a faint aromatic taste. On warming there is a separation of the water and formation of terpin, $C_{10}H_{18}(OH)_2$. The development of tubercle bacilli is arrested by a 0·25 per cent. solution (*Colpi*). It has been used internally in lung and kidney diseases (*Manasse and Talamon*).

"Terpineol" is the product obtained by boiling terpin or terpin hydrate with dilute mineral acids. According to Wallach, it is a mixture in variable proportions of terpineol ($C_{10}H_{18}O$) and several terpenes. Guelpa and Morra have proposed it as an antiseptic in cases of bronchitis. Yarnold patented[4] antiseptic ointments or lotions prepared by mixing

[1] Patent No. 11,963, 1884.
[2] *Lancet*, vol. xi, 1890, p. 724.
[3] *Brit. Med. Journ.*, 1898, i., 702; *Lancet*, 1898, i., 37.
[4] No. 20,034 of 1900.

with suitable ingredients the viscid or syrupy product obtained by the action of ozone on terpineol, and antiseptic and disinfectant solutions obtained by blowing ozonized air through terpineol mixed with water (see Sanitas).

H. Marx[1] has investigated the action of various perfumes on cultures of B. anthracis and Staph. pyog. aureus. Growth is prevented by 1 in 1,000 of terpineol or 1 in 100 of nitrobenzene in the fluid, while agar plates are completely or partially sterilized if a drop of either of these be added, or if they are partly covered with heliotropin or vanillin. Even a relatively short treatment with terpineol 1 in 500 or nitrobenzene 1 in 10 produces such a change in these bacteria that afterwards they develop only slowly. Terpineol 1 in 100 kills anthrax, and 1 in 10 kills staphylococci in 60 minutes, while 1 in 10 nitrobenzene kills neither in 24 hours. Terpineol shows a specially strong action when mixed with a foaming potash soap. In emulsions of bacteria, perfumes, particularly terpineol, effect agglutination, but it is doubtful whether this plays a part in the bactericidal action. This author considers rather that the latter is connected with the property of rendering oxygen active.

Absynthol is an isomer of camphor from oil of wormwood.

Borneol or Borneo camphor, $C_{10}H_{18}O$, from *Dryobalanops camphora*, a white crystalline solid with an odour like pepper, resembles ordinary camphor in properties, but Seloni finds it slightly more antiseptic.

Camphoid, though in itself only feebly antiseptic, is a useful vehicle for applying more active agents to the skin, and forms a protective coating. It is a mixture of camphor, pyroxylin, and alcohol. Several so-called disinfectant washing powders have been patented. These usually consist of a mixture of disinfectants with soda crystals. R. P. Hicks[2] makes a saturated solution of sodium carbonate in boiling water, and then on cooling, as it crystallizes, a mixture of diamylene (or decylene, $C_{10}H_{20}$), camphene (one of the terpenes, $C_{10}H_{16}$), menthene, terebene, cymol, thymol, and sometimes phenol is added.

[1] *Centr. Bakteriol.*, 1903 [1] xxxiii., 74.

[2] Patent No. 6,209, 1887.

"Camphylene" (Fleming) is a solid disinfectant which is said to contain "a crystalline hydrocarbon allied to camphor, with several alkaloidal bodies, all evaporating spontaneously, without admixture of mineral substances."

Many of the essential oils are used in disinfecting powders. Under phenol (p. 205) the bases of the most common powders have already been mentioned. Lime, magnesia, and alkaline bases unite with the disinfectant when it has acid properties. The volatile oil is then only slowly evolved by the action of the carbonic acid of the atmosphere. Sand is too coarse for general use, but infusorial earth and artificial silica (*Calvert*), being inert bases, give off the volatile matters completely. For use in wet places, such as urinals, inorganic bases are the best; while for stables, rooms, etc., sawdust and peat are most serviceable. Plaster of Paris and cement are sometimes used; whilst dry earth and burnt clay are suitable for rough work.

The Oxidizing Power of Essential Oils.—Sanitas.—Schönbein first observed that in all slow processes of oxidation a small quantity of the oxygen is converted into ozone, as in the low combustion of phosphorus. If any organic matters be present, they are rapidly oxidized by the ozone formed. He remarked that oil of turpentine and other essential oils were specially active in this way, and that ozone, probably from being continually re-formed, was permanently present in small amount as long as any oxygen was left.

He attributed the purifying action of perfumes entirely to this ozonizing effect. But Angus Smith[1] proved by experiments that the explanation was not sufficient, and that their antiseptic action must also be taken into account. He suspended ozone paper (blotting-paper dipped in potassium iodide and starch paste) in a large flask containing a thin layer of the essential oil, and judged the amount of ozone by the degree of blueing of the paper, taking 10 degrees as an arbitrary maximum. He gives the following table:—

[1] *Disinfectants*, Edinburgh, 1869, p. 118.

	Degree of Blueing of the Ozone Paper.			
	After 18 hours.	24 hours.	48 hours.	72 hours
Oil of Orange-peel ...	Considerable.	Strong Colour.	9	10
Essence of Turpentine	Feeble.	Distinct.	7	9
Oil of Juniper	Considerable.	,,	5	5
,, Cumin	None.	None.	2	2·5
,, Lavender ...	,,	,,	2	2·5
Cresol	,,	,,	2	2
Phenol, pure	,,	,,	None.	1
Creosote (Wood) ...	,,	,,	,,	None.
Pyroligneous Acid ...	,,	,,	,,	,,
Camphor	,,	,,	,,	,,
Oil of Thyme	,,	,,	,,	,,
Naphthalene	,,	,,	,,	,,

This test is not very delicate, but there is no doubt that traces of ozone are produced with all the above compounds except naphthalene. Other observers have found oil of thyme to give more than cresol. Yet the fact is obvious that the antiseptic action is not proportional to the small quantity of ozone formed, though the slight disinfectant power may be. Although, relatively, there is only a mere trace of ozone, amounting perhaps to 1 in 1000, nevertheless it may form a considerable quantity in a large volume of air.

Scoutteten[1] found that ozonised air rapidly removed the odour of foul manure; Richardson and Wood, that of putrid blood that had been kept in a flask for two years. Bond attributed the disinfecting action of permanganate to its production of ozone.[2] Boillet proved that ozone not only destroyed a putrefactive odour already formed, but actually prevented putrefaction.[3] Chapuis collected the germs and dust from contaminated air by filtering it through cotton wool; he then submitted some of the wool plugs to the action of ozonised air. On then placing the wool in a nutrient solution (wort), the untreated plugs caused rapid turbidity and growth, the ozonised ones remained clear for twenty days.[4] From the known fact that the hygienic condition of a locality varied with the proportion of ozone in the air, as shown by test papers, and that several epidemics had been

[1] *L'Ozone*, Metz, 1856.
[2] *Brit. Med. Journ.*, 1875, p. 239.
[3] *Comptes rendus*, 1875, p. 1258.
[4] *Bull. Soc. Chimique*, 1881, p. 290.

preceded by a sudden fall in ozone, he very naturally argued that ozone must have the power also of destroying pathogenic organisms.

Miquel showed that ozone attacks gaseous emanations before it acts on bacteria or spores. Subsequent investigations have proved that it does attack the latter (see *Ozone*).

Thenard was one of the first to show, and Ireland,[1] Barlow,[2] and others to confirm, that this gas is a poison, and was capable of causing asphyxia and fatal bronchitis, and that even a very minute quantity was irritant to the mucous membranes. These facts have a direct bearing on the claim of many advertised "disinfectants" to give ozone. The odour of turpentine, the smell of a newly-painted house, even the proximity of a pine forest, though supposed to be good for consumption and pulmonary complaints, undoubtedly cause in many people considerable irritation of the eyes, nose, and lungs. Still, in most cases, the freedom of the air from germs produces manifest improvement.

C. T. Kingzett, about 1874, noticing that in presence of excess of warm water, peroxide of hydrogen, which is not irritant, is produced in solution rather than ozone, together with oxidation products of the terpenes, which acted as strong antiseptics, introduced a new disinfectant under the name of "Sanitas." In the first patent[3] turpentine oil is floated to a sufficient depth on the surface of warm water in large jars called oxidizers, and currents of warm air or oxygen are forced through the mixture continuously for seven to ten days, maintaining the temperature constantly at 60°. The proportions used are 9 parts of turpentine oil to 1 of water.

Berthelot has also shown that oil of turpentine is capable of dissolving from 3 to 5 per cent. of oxygen. The action in the presence of water is, therefore, of a dual character, the atmospheric oxygen simultaneously producing peroxide of hydrogen (which dissolves in the water and oxidizes the turpentine, yielding camphors, camphoric acid, resins, minute quantities of formic acid, cymene, etc.), and a substance named by Kingzett "camphoric peroxide." Part of these products dissolve in the water, part remain in the oil, with the formation of:—

[1] *Annales d' Hygiène*, vol. xix., p. 439.
[2] *Journ. of Anat. and Physiol.*, 1879.
[3] No. 274, 1876.

1. "Sanitas fluid," of a light straw colour and pleasant aromatic odour. It contains camphoric acid and camphoric peroxide, and gives a distinct purple reaction with sulphuric acid and potassium bichromate, showing the presence of hydrogen peroxide, amounting, according to the *Lancet*, to such a proportion that twice its volume of oxygen is given off when it is decomposed.

2. "Sanitas oil," a brown syrupy liquid, lighter than water, and insoluble in it, but soluble in alcohol, and having a similar odour to that of the aqueous fluid. When shaken with water, it imparts a peroxide of hydrogen reaction which is not so strong as that produced by the fluid.[1] It burns like camphor with a sooty flame.

Patent No. 5,572, 1882, added resin and resin oil, and camphor or thymol. Turpentine, oil of eucalyptus, and "camphor oil" are also among the ingredients used.

The "Sanitas air purifier" consists of fine wood flour impregnated with camphoric peroxide. A Sanitas toilet soap is made, and soft soaps, veterinary washes, and emulsions of the oil with gums, etc. Patent No. 1,589, 1890 (*Kingzett*), refers to "oxidized turpentine mixed with soft or hard soap." In patent No. 276, 1887, it is proposed to use:—

1. Tin instead of earthenware for storing, as Sanitas is not corrosive to metals.

2. Sea water instead of ordinary water, as the hydrogen peroxide keeps better in a saline solution.

3. "One or more antiseptics added before or after oxidation."

Horgreaves[2] mixes Sanitas oil and other disinfectants with laundry blue for linen.

Kingzett mounted at the same time a series of vessels containing equal quantities of standard meat extract mixed with respectively 5 parts in 100 of a 5 per cent. solution of various metallic antiseptics, 5, 10, 15 and 20 per cent. of ordinary Sanitas fluid, and 5 per cent. of "Mercuric Bactericide" (5 per cent. of mercuric chloride in a "five volume"[3] solution of peroxide of hydrogen). The mixtures broke down and became putrid in this order:—3rd day, the standard solution; 5th day, zinc sulphate, lead nitrate; 6th, the 5 per cent. Sanitas mixture; 7th, lead and tin chlorides;

[1] *Lancet*, vol. i., 1890, p. 809. [2] Patent No. 2,524, 1883. [3] See p. 118.

12th, mercury nitrate, ferric and aluminic chlorides; 15th, chloride of zinc; 21st, zinc nitrate: 34th, the only mixtures remaining unputrefied were those with the chlorides and sulphates of copper and mercury, the "mercuric bactericide," and those with 10 per cent. and upwards of Sanitas Fluid. "It follows that the latter has a powerful inhibitive action, and that 10 c.c. of it is equal in antiseptic effect to 5 c.c. of a 5 per cent. solution of corrosive sublimate."

We have already referred to the difficulty of disinfecting, by means of salts of heavy metals, solutions containing organic matters and phosphates, on account of the metal being precipitated.

Dr. Weeks reports in the New York *Medical Record* of August 3rd, 1889, that he found with Staph. pyog. aureus and B. typhosus that Sanitas oil destroyed their vitality in 23 seconds, the "Crude Disinfecting Fluid" in 1½ minutes, the "Disinfecting Fluid" in 4 minutes, and the same of 50 per cent. strength in 10 minutes.

H. Crowther observed that an equal volume of Sanitas Fluid did not impair the efficiency of vaccine lymph, hence it might be used for the preservation of the latter.[1]

Tripe and Stevenson[2] and Longstaff and Hare,[3] after numerous experiments, arrived at the conclusion that "the Sanitas fluid and powder do not disinfect better than slaked lime"; they recognize, however, that this substance retards putrid decomposition, but that "it is little active in deodorizing substances already putrid."

It is obvious that Sanitas, like some other preparations, has suffered by being over extolled; its chief points of interest are:—

1. The "fluid" is non-poisonous, non-corrosive, and does not stain.

2. It certainly oxidizes most organisms and their products when in sufficient quantity and strength, say 1 or 2 parts per 100.

3. Its action on sulphuretted hydrogen is not great, that on ammonia is almost *nil*. It can, however, be used with an absorbent like chloride of zinc, but not with ferrous sulphate, sulphurous acid, or other reducing agents.

[1] *Med. Times and Gaz.*, 1879, p. 361.

[2] *Med. Times and Gaz.*, 1880, p. 51, "Disinfectants in contradistinction to Deodorants and Antiputrefactive agents."

[3] *Sanitary Record*, 1878, p. 353.

4. Its price is decidedly higher than some other disinfectants, if quantity required be considered. A "Sanitas water-cart block, consisting of Sanitas in a highly concentrated (solid) state," intended to be placed inside the cart for disinfecting streets, has been introduced, but it is more than doubtful whether this could be done efficiently except at a prohibitive cost.

5. It is valuable for toilet use when a persistent odour is not an objection. Many people find it very agreeable. It ranks about equal to sodium hypochlorite (liquor sodæ chlorinatæ, p. 85).

6. More evidence as to its stability or constancy of composition is required.

7. Further independent investigations as to its efficacy in epidemics like typhoid, cholera, etc., as to the poisonous dose of "Sanitas oil," and whether it has irritant external effects, seem also desirable.

Kingzett calculates that the eucalyptus forests of New South Wales and South Australia alone contain, at any moment, sufficient oil in the leaves, ready to be evaporated into the atmosphere under the agency of warm winds, to form no less than about 93 million tons of peroxide of hydrogen, and 507 million tons of camphoraceous principles.[1] The same observer showed[2] that small quantities of alcohol, ether and especially thymol, greatly retard the decomposition of hydrogen peroxide, and on this the Sanitas Company have based a "patent preserved peroxide of hydrogen."

A fluid called "PINOL" is advertised, derived from *Pinus pumilo*. It resembles other terpene preparations, but is somewhat more pleasant in odour.

The general name of "peroxols" has been applied in Germany to a series of mixtures of hydrogen peroxide with menthol, thymol, camphor, phenol, salicylic acid, quinine sulphate, or zinc chloride. In order to obtain clear liquids, miscible with water without precipitation, 33 to 38 per cent. of alcohol is added. "Menthoxol," for example, has one per cent. menthol and 33 per cent. alcohol in 100 c.c. of 3 per cent. hydrogen peroxide solution.[3]

[1] *Social Science Congress, Manchester*, 1879; also see the same author's *Nature's Hygiene*. [2] *Journ. Soc. Chem. Ind.*, Jan., 1890.

[3] M. Beck, *Zeits. f. Hygiene*, 1901, xxxvii., 294.

CHAPTER XI.

COMPOUNDS RELATED TO THE ALCOHOLS.

Methyl Alcohol: Wood Spirit—Methyl Chloride—Chloroform—Methene Dichloride. Formic Aldehyde and "Formalin": Properties and Disinfectant Value — Action on Bacteria — Generators — Other Aldehydes. Ethyl or Ordinary Alcohol: Not a Reliable Antiseptic. Formic Acid and Sodium Formate. Acetic Acid: Aromatic Vinegar—Action of Vinegar on Bacteria —Pyroligneous Acid. Glycerine: Its Uses and Limitations. Oleic Acid, Oils, and Fats: Lanolin. Hydrocarbons: Acetylene. Vegetable Acids: Tartaric, Citric, Malic, Oxalic, Succinic.

Methyl Alcohol, $CH_3.OH$, closely resembles ethyl alcohol, but boils at a lower temperature, 66° C. In the crude form of wood spirit it has long been used to preserve anatomical specimens, owing its efficiency in great part to the creosote, etc., it contains. It is fatal to insects and micro-organisms in the moderate proportion of about 5 per cent., and were it not for its volatility and the fact that its vapour when mixed with air is explosive as well as narcotic, it would take a high rank as an antiseptic. Its relative cheapness makes it a better vehicle for those aromatic antiseptics which are insoluble in water than ethyl alcohol, which is commonly used.

Tollens has devised a lamp for the slow combustion of methyl alcohol, forming formaldehyde vapours.[1]

Methyl Chloride or monochlormethane, CH_3Cl, is a colourless gas of sweetish odour, soluble in water, and neutral, compressible by a pressure of 3 to 7 atmospheres into a colourless liquid, boiling at 21° C., in which state it is sold in commerce in iron cylinders. Its vapour is antiseptic, but no experiments are extant as to its relative value.

Methylene Dichloride, CH_2Cl_2 (boiling point, 42° C.), is very similar to, but less powerful than, chloroform.

Chloroform, trichlormethane, $CHCl_3$, has already been referred to (p. 102).

Formic Aldehyde, or Formaldehyde, H.COH, is only known in solution, "Formalin," and in a state of vapour, since if an attempt be made to condense it, it polymerises to a white crystalline solid called para-formaldehyde or trioxymethylene, $C_3H_6O_3$. Formaldehyde is readily soluble in

[1] *Ber. d. deutsch. Chem. Gesells.*, 1895, vol. xxvii., p. 261.

water, giving, if perfectly pure, a neutral solution; commercially it is always slightly acid, from the presence of a little formic acid.[1] The odour is pungent, causing irritation to the eyes and nose: beyond this action it is not poisonous. The aqueous solution is stable when kept in well-closed bottles, but loses some of the gas on exposure. Loew and Fischer, in 1886,[2] discovered that it possessed powerful antiseptic properties; Trillat, in 1888, showed that the presence of a minute quantity of this substance in urine effectually preserved it from putrefying. In a further paper he remarks that "hitherto it has been thought that the most powerful antiseptic bodies belonged to the hydroxyl compounds of the aromatic series of hydrocarbons (the phenols) and to the metallic salts. Formaldehyde is, however, a very powerful antiseptic, being actually superior to bichloride of mercury in this respect. The result is quite unexpected, as acetic aldehyde does not possess this property."[3] It is prepared by passing methyl alcohol vapour mixed with air over a red hot platinum spiral or heated platinised asbestos, condensing and purifying the vapours.[4]

Buchner,[5] Aronson,[6] and F. Cohn,[7] have investigated the properties of formaldehyde, while Lehmann, Gegner, and Blum[8] have examined its value as a general disinfectant, and Stahl,[9] Hauser,[10] and Liebreich[11] have reported on its suitability for special purposes. All these writers are agreed in attributing to formaldehyde powerful antiseptic and deodorant properties. Blum, however, points out that micro-organisms are only killed in somewhat strong solutions (2 per cent.). In 1894 C. Slater and the author confirmed Blum's statement.[12]

With reference to the antiseptic power of formaldehyde, Trillat states[13] that "the addition of 1 to 50,000 of meat

[1] G. Bruni states that the acid solutions are much more fatal to micro-organisms than the neutral ones (*Chem. Centralblatt*), 1900, 51.

[2] *Journ. f. praktische Chemie*, vol. xxxiii., p. 221.

[3] *Moniteur Scient.*, 1892, p. 490.

[4] Trillat and Berlioz, *Compt. rend.*, vol. cxiv., p. 1,278; cxv., p. 290; cxix., p. 563.

[5] *Münch. Med. Wochenschr.*, 1889, No. 20. [6] *Berlin Klin. Woch.*, 1892, p. 749.

[7] *Botan. Centralblatt*, 1894, p 573.

[8] *Münch. Med. Woch.*, 1893, p. 32.

[9] *Pharm. Zeit.*, 1893, p. 22. [10] *Münch. Med. Woch.*, 1893, pp. 567 and 655.

[11] *Therap. Monatschrift*, vol. iv., p. 183.

[12] *Lancet*, April 21, 1894.

[13] *Moniteur Scientifique*, 1892.

extract had a decided preservative action, while with 1 in 25,000 no change could be noticed in the extract after the lapse of four days. Mercuric chloride in these proportions has no effect, the extract showing change in twenty-four hours. With 1 in 12,000 the extract is kept good for several weeks, while change occurs in five days when using an equal weight of mercuric chloride. Several kinds of bacilli are destroyed by a solution of 1 in 25,000, such as that of the saliva, etc." For the preservation of meat, Trillat tried (1) immersion in the solution, (2) exposure to the vapour, (3) wrapping the goods in coverings soaked with the aldehyde solution. One hour's soaking in a 1 in 500 solution preserved the meat for twenty-five days; five minutes with a 1 in 250 solution kept it for twenty days, when exposed to air at 23° to 30° C. "The vapour was found to stop all decomposition, keeping meat fresh for months and stopping fermentation in organic liquids."

Cambier and Brochet showed that the vapour of formaldehyde produced by heating paraformaldehyde effects the complete sterilization of household dust.[1]

Slater and Rideal's re-examinations,[2] in which formaldehyde was added to tubes of *bouillon* in proportions varying from 1 in 1,000 to 1 in 20,000, the tubes then inoculated with vigorous cultures of different micro-organisms, and placed in an incubator, showed the following results for inhibitory action :—

Organism.	Proportion of Formaldehyde Inhibiting Growth.	Proportion allowing some Growth.	Remarks.
Staphylococcus pyogenes aureus ...	1 in 5,000	1 in 10,000	Growth poor—1 in 10,000, and much delayed 1 in 20,000
Bacillus typhosus	1 in 15,000	1 in 20,000	Very scanty growth
,, *coli communis*	1 in 7,000	1 in 10,000	After seventy-two hours' incubation.
,, *anthracis*	1 in 15,000	1 in 20,000	Scanty growth on sixth day.
Spirillum choleræ	1 in 20,000	...	...
Bacillus mallei	1 in 20,000	...	..
,, *pyocyaneus*	1 in 7,000	1 in 10,000	On the third day
,, *lacticus*	1 in 20,000	...	...
,, *butyricus* (Hueppe) ...	1 in 20,000	...	...
Micrococcus prodigiosus	1 in 20,000	...	...

[1] *Compt. rend.*, vol. cxix., p. 607.
[2] *Lancet*, April 21, 1894.

The authors remark, "This would place formaldehyde among the first three or four antiseptics in Koch's tables. It is to be noticed that even when the proportion is too small to prevent growth, the cultures then obtained are scanty, and their development is long postponed. The fact that growth does not take place in the *bouillon* is not proof that the microbe has been killed. Thus *Bacillus malleï*, which showed no growth after four day's incubation in a 1 in 15,000 strength, when transferred to a fresh nutrient solution, gave rise to a culture normal in all respects, except in requiring an unusually long time to develop. Blum has shown with regard to anthrax that exposure to the antiseptic does not cause attenuation." As to commercial yeast, 1 in 2,500 of wort was required to prevent fermentation. In lesser quantity the rapidity was diminished, but the final amount of alcohol was the same as if no antiseptic had been added. Hence formaldehyde can arrest secondary fermentations in alcoholic liquids.

W. Kinzel carried out a series of experiments to determine the utility of formaldehyde for the destruction of mildew in seeds, using wheat, rye, oats, barley, clover, lupin, pea, and also the fungus, *Ustilago segetum*, from green, half-ripe, and ripe oats. He found that a 1 in 1,000 solution destroyed the fungus in 1 hour, and that there was no objection to its use.

To determine the amount required to kill microbes, Slater and Rideal soaked sterilized silk threads in various cultures and transferred them to the diluted formaldehyde. After different intervals the threads were withdrawn, well washed in sterile water, transferred to bouillon tubes, and kept at 37° C. for more than eight days. The tubes in which no growth took place were tested by inoculation in order to determine whether they were still suitable for growth of the microbes or whether the sterility was due to transferred antiseptic. They all yielded copious growth on second inoculation. Control experiments were made in all cases. The results obtained were:—

"Time required to kill the microbes with a 1 per cent. solution: *S. pyogenes aureus*, between 50 and 60 minutes; *B. typhosus*, 40 to 50; *B. coli communis*, 30 to 40; *B. anthracis* and *S. choleræ*, less than 15 minutes.

"With a 1 per 10,000 solution (threads examined every half hour, at first, then hourly, then every twenty-four hours),

B. anthracis (no spores) killed in thirty minutes; *S. choleræ* in two hours; but putrefaction organisms were not killed after twenty-four hours. Experiments were made to see how far these solutions might replace the 1 or 2 per cent. solution of carbolic acid frequently used for the disinfection of soiled linen before washing. Soiled clothes from the *post-mortem* room and sterilized clothes soaked in cultures were left for from twenty to twenty-four hours in 1 per cent. and 1 per mille solutions of formaldehyde. After washing in sterile water they were examined by cultivation :—

	1 per cent. solution.	1 per 1,000.
Clothes from *post-mortem* room	Sterile	Not Sterile
Clothes soaked in *B. typhosus*, *Spirillum choleræ*, or *St. pyog. aureus*	,,	Sterile

"The solutions are without any ill effect on clothes, and are efficient as antiseptics, more especially the 1 per cent. solution, and the more so as in practice the adherent formaldehyde solution would not be removed." It seems especially suited for the disinfection of leather goods and general articles, like combs and brushes, which cannot be satisfactorily sterilized in other ways.

The action of the vapour evolved at 19° C. from a 40 per cent. solution was examined by exposing to it glass slips of dry bouillon cultures under a bell-jar for ten minutes. *B. typhosus* and *coli*; *M. prodigiosus* and *Sp. choleræ* were killed in less than ten minutes; *S. pyogenes aureus* in twenty; *B. pyocyaneus* in thirty minutes. As to the disinfection of rooms, 1½ ounce of 40 per cent. formaldehyde was evaporated by a spirit lamp in a room of 1,548 cubic feet (about 11½ feet side). The dust was disturbed by vigorous sweeping, then examined bacteriologically. After four hours' exposure to the vapour, the dust was again disturbed, and a sample examined. In other experiments threads soaked in various cultures were suspended at different heights and at about 3 to 5 feet from the source of the vapour. The results were not decisive, but showed marked effects from the vapour. There is no reason why much larger quantities of the antiseptic should not be used. The air before disinfection contained 429 organisms for 10 litres, afterwards only 71. The threads after disinfection in all

cases produced more scanty cultures and more slowly. Some of those impregnated with *B. typhosus* and *coli* were sterile.

It seems also to be possible to sterilize the skin with formalin, which does not hinder the formation of a lather with soap, as mercuric chloride does. Landerer and Krämer[1] point out that the ordinary method of disinfecting the seat of a proposed operation by scrubbing, and the application of ether and some antiseptic solution, acts merely on the surface of the skin, and does not attack any micro-organisms which may exist in the cutaneous glands, and which can be reached only by a disinfectant in a gaseous form. These authors state that they have used for some time a 1 per cent. solution of formalin with very good results. Compresses dipped in this solution and covered by some impermeable material are applied to the skin at the seat of operation, and allowed to remain with one or two renewals from twelve to thirty-six hours; over this time the application is apt to cause hardening of the skin, and so interfere with primary union. This use of formalin is regarded as only a preliminary measure, and should not lead to any omission in careful cleansing and disinfection of the skin immediately before the operation.

Trillat states that formaldehyde precipitates the tannin and colouring matters of wine. It is incompatible with ammonia, forming with it a non-volatile crystalline compound, hexamethylene-tetramine (p. 248). Formaldehyde is a reducing agent.

In commerce it is found as "Formalin" or "Formol," a solution in water containing about 40 per cent. of the aldehyde, with a minute trace of formic acid, made by Schering of Berlin.

Berlioz and Trillat say that the vapour can be inhaled or injected in throat and lung disease with marked benefit and without toxic effects.[2] J. Stahl generally confirms the value of formaldehyde.[3]

Ethyl aldehyde and paraldehyde seem to be useless as antiseptics. Chloral has properties similar to those of chloroform.

[1] *Centralbl. für Chir.*, No. 8, 1898.
[2] *Comptes rendus*, vol. cxv., p. 290.
[3] *Pharm. Zeit.*, 1893, p. 173.

Within the last few years disinfection with formaldehyde has become more widely used, and a large amount of experimental work has been done on this subject.

In the Slater and Rideal investigation just recorded the quantity employed corresponds to 0·4 oz. formaldehyde per 1250 oz. of air or ·032 per cent. by weight. As formaldehyde has practically the same density as air, this is also ·032 per cent. by volume. There have since been introduced three distinct methods of applying formaldehyde to room disinfection, which possess advantages over the method then adopted. They are:—

(1) Spraying the walls, ceiling, and floor with the solution.

(2) Atomizing the vapour from a calcium chloride solution under pressure in an autoclave.

(3) Vaporizing paraformaldehyde by means of heat in the presence of water vapour produced from the products of combustion of methylated spirit.

(1) The Sprayer (Equifex Apparatus).—This instrument consists essentially of a cylinder fitted with two tubes, through which air and the disinfectant are separately driven by a pump to be united at the end in a spray of 4ft. to 6ft. long.

Dr. Kenwood at the Leeds Conference of the Sanitary Institute in 1897, suggested the use of 2·5 per cent. solutions of the aldehyde for spraying, and Drs. Thresh and Sowden, from experiments at the London Hospital,[1] concluded that whitewashed surfaces were more difficult to disinfect than surfaces of wood and paper, and that "solutions containing under 1 per cent. of chinosol or 2 per cent. of formaldehyde were not absolutely reliable." We may remark that only one failure with ½ per cent. (B. pyocyaneus), and one with 1 per cent. (S. pyog. aur.) are recorded in their paper out of 36 experiments, in which these organisms in all other cases, and B. diphtheriæ, typhosus, M. prodigiosus and Sp. choleræ in every case, were killed by the ½ and 1 per cent. sprays. Drs. Leslie Mackenzie and Alexander, at Leith and Poplar, report that they use with success 2 oz. of formalin per gallon,

[1] *Journ. San. Inst.*, Jan. 1903, p. 515.

or a 0·5 per cent. solution of formaldehyde. This is the strength which I have advocated for some time as sufficient for all general purposes, and far in excess of that required to inhibit the growth of most commonly occurring organisms (see table, p. 296). The 0·5 per cent. solution then, being 35 to 100 times stronger than is necessary to kill the above organisms, I am of the opinion that Dr. Kenwood's strength of 2·5 per cent. is much too high. Dr. Mackenzie, after an experience of 400 cases, in which after the spraying there was no infection, states that there is no difficulty in respiration felt by the disinfector using the 0·5 per cent. strength, whilst the higher strength would, I believe, be usually found somewhat irritating to work with. There is great risk of imperfect spraying except with a good apparatus in the hands of an experienced operator, and therefore the spraying with a 0·5 per cent. solution should in all cases be supplemented by the use of one of the appliances for generating the moist gas, so as to ensure the disinfection by vapour of crevices and parts of the room or furniture missed by the spray. In most cases, as shown below, the vapour treatment is sufficient, but where we are dealing with an unknown organism like small-pox, when the walls and room are exceptionally dirty, or where very special disinfection is needed, as in plague, both methods should be used.

(2) The Autoclave (Trillat's System).—Trillat observed that, when heated under a pressure of two or three atmospheres, nearly the whole of the formic aldehyde in a solution may be evolved as gas without the polymerization that occurs when heated in the ordinary manner, and that the production of the active gas is assisted by the addition of neutral mineral salts such as calcium chloride. His apparatus consists essentially of an ordinary steam autoclave, heated by means of gas or a Swedish petroleum lamp. "Formochloral," which is formalin of 40 per cent. containing in solution about 10 per cent. of calcium chloride,[1] is placed in the body of the apparatus, 1lb. being said to be sufficient for "an ordinary-sized room,"—say 1500 cubic feet.

[1] Rosenau states that in similar apparatus in America 20 per cent. of calcium chloride, "or some other neutral salt, such as borax or common salt" is used, and that not less than 10 ounces of the solution is allowed per 1000 cub. ft.

When a pressure of 35-40 lbs. has been reached, corresponding to a temperature of 135° to 140° C., which takes about 30 minutes, the gas can be introduced into the sealed room by means of a fine copper tube or jet, passing through the keyhole of the door and controlled by the valve on the top of the autoclave, which is worked outside the room. According to the amount of the charge from twenty minutes to one

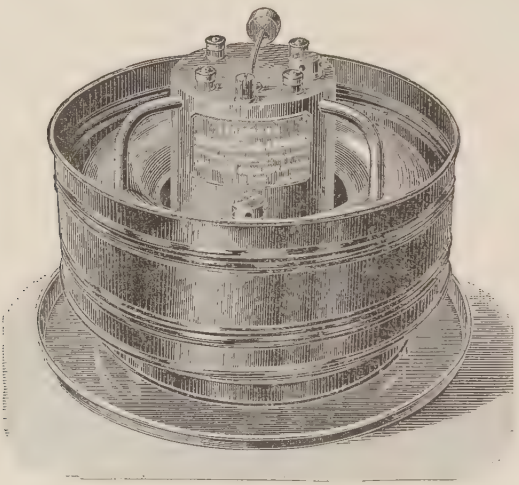


Fig. 18.—Lingner's Formaldehyde Generator (see p. 315).

hour is required to discharge the gas, the pressure being maintained throughout the operation.

Dr. Kenwood obtained perfect sterilization of diphtheria swabs with this apparatus, and observes in his Leeds paper:

"(1) When the air is charged with from ½ to 2 per cent. of formaldehyde, the disinfection of all surfaces is complete and rapid, and that this holds good under the ordinary conditions of temperature and moisture obtaining in living rooms.

"(2) The vapours possess a certain and variable amount of penetrating power into loose fabrics, especially when these are dry. This penetration is largely due to the circumstance that when produced in a warm state the vapour is of a low specific gravity and mixes well with the air.

"(3) That the vapours do not affect the colours of textile materials, etc., or (with the exception of iron or steel) metallic surfaces.

"(4) That the room and articles exposed can be cleared of the vapours readily by sufficient aëration, and the vapours are not so irritating but one can always enter the room and unseal at the first attempt (an advantage over SO_2 and Cl).

"(5) That the disinfecting properties of the aldehyde are greater than those of SO_2 or Cl.

"(6) That there is no danger in entering the room, either from the aldehyde or from the CO which is formed at the same time. This is proved from the fact that the men employed in the works and exposed to considerable quantities enjoy good health, and also from many experiments with animals in atmospheres heavily charged with the vapours generated as in room disinfection. . . .

"The apparatus costs about £18, and the disinfection of an ordinary-sized room would cost about 2/6. Half-an-hour is required to get up the necessary pressure, and then the vapours must be allowed to escape into an ordinary-sized room for half-an-hour, and for an hour in a very large room."

Dr. Sims Woodhead said, in the Leeds meeting, that in his trials of the autoclave at the College of Physicians unsuccessful results were obtained. My own experiments with Trillat's apparatus were more satisfactory. The receptacle was charged with 1 lb. of the "Formochloral,"[1] and the gas under a pressure of 35 to 40 lb. was passed into a sealed room with a capacity of 1,500 cubic feet. There were exposed in Petri's dishes in different parts of the room silk threads, paper slips, and pieces of folded linen. Immediately before closing the room these were severally inoculated from active cultures of the following organisms: (1) B. subtilis containing spores, (2) B. coli communis, (3) Staph. pyogenes aureus, (4) B. typhosus, (5) B. diphtheriæ, (6) B. anthracis containing spores. After twenty-four hours' exposure the silk threads were all sterile; the slips of paper, including those impregnated with anthrax spores, were sterilized with the exception of B. subtilis; the folds of linen

[1] It is regrettable that a name causing confusion with "chloral" should have been chosen.

gave impure sub-cultures, but the specific organism could not be isolated from each, and the linen infected from the typhoid culture was quite sterile. Equal quantities of dust taken (1) before and (2) after the disinfection, from beneath the carpet gave (1) colonies too numerous to count, (2) fifty colonies on nutrient gelatine plates. The number of growths obtained from the air fell from 68 per 2½ litres to *nil* per 5 litres. The carpet, furniture, metal, and leather articles purposely exposed in the room during the disinfection were not damaged in any way.

Trillat's apparatus has been adopted by the municipality of Marseilles for quarantine disinfection of vessels from India.

Dr. Wynter Blyth, in a report to the Marylebone Vestry, compared the Trillat method very favourably with the sulphur process of disinfection, and summarized his results as follows:—

"*Results of Cultivation after Forty-eight Hours' Incubation at Blood Heat.*

	Sulphur gas.	Formic aldehyde gas.
I.—Diphtheria bacillus... ...	No growth	... ... No growth
II.—Typhoid bacillus	Good growth	... ... No growth
III.—Anthrax bacillus	Good growth	... ... No growth

"1. Formic aldehyde gas is a valuable and true disinfectant, and exercises no appreciable destructive action on fabrics or colours.

"2. It is superior to sulphur gas.

"3. It should be used in preference to sulphur gas in certain cases, especially where fumigation alone has to be trusted to."

Bose, Vaillard and Lemoine, and Pfühl report favourably on the Trillat system.

Dr. Kenyoun[1] states that results of his experiments "demonstrate that formalin gas is a reliable disinfectant for surfaces and for lighter articles, such as curtain hangings, clothing, carpets, and bed coverings. The gas was germicidal in all save where the test cultures were tightly wrapped in many layers of fabrics. Interiors of books were

[1] *Washington Public Health Reports*, January, 1897.

difficult to disinfect. It is doubtful whether the interior of articles, such as upholstered furniture, mattresses, and pillows can always be disinfected, unless a much larger percentage of gas is applied than was used in the above experiments (0·25 to 2 per cent.). *It follows that the length of the exposure is secondary to the amount of gas used.*

"Experiments were made by subjecting samples of wool, cotton, fur, and leather goods of every description to crucial tests, using solutions of various strengths and a saturated atmosphere of gas. The results obtained were in every way satisfactory. Of over 225 different samples of wool, silk, cotton, linen, leather, and hair subjected, there was no change observed in textile character." Only three of the number showed any change of colour, namely, two shades of violet and a light red. "These were coal-tar colours and were also quickly bleached by the sun.

"Iron and steel are attacked by the gas, and more so by its solutions. Copper, brass, nickel, zinc, and gilt work are not acted upon. The effects of the substance on iron should be borne in mind if iron disinfecting chambers are used for applying the gas. If this be the case, the surface of the interior of the chamber should be protected by paint or varnish. After subjecting textile fabrics to the action of the gas, there always remains a considerable quantity of formaldehyde in combination with the materials, which is slowly given off for a considerable time thereafter. This is especially so in the case of mattresses and feather pillows. It is best obviated by subsequently exposing the article to the fumes of ammonia, which neutralizes the formaldehyde by converting it into formamide[1]—a rather stable body—possessing germicidal properties of no small value, and not prone to undergo decomposition."

(3) Formaldehyde Lamps.—It has already been shown that good results cannot be obtained by the simple evaporation of a concentrated solution of formaldehyde, as, owing to various causes, the maximum amount of the gas is not obtained. R. G. Wilson,[2] from experiments in railway carriages, concluded that the suspension of sheets moistened with undiluted formalin (40 per cent. formaldehyde) was

[1] Or rather *hexamethylenetetramine*, p. 248.

[2] *New York Bull. Med. Sciences*, Oct., 1901.

wholly inefficient. The dry heated air caused further concentration and polymerization, so that the formaldehyde lost its volatility. A similar observation was made by Dr. Lübbert in German South-West Africa.[1]

Many lamps for aërial disinfection have been proposed upon the principle that formaldehyde can be generated when the combustion of a mixture of methyl alcohol vapours and air takes place over red-hot platinum (Hoffmann). Such lamps have been devised by, among others, Tollens, Bartel, Robinson, Trillat, Broche, Schweinertz, and Dieudonné.

Bartel dispenses with the use of platinum, the methyl alcohol being warmed in a kettle, the spout of which is heated by a spirit lamp sufficiently to ignite the issuing vapours, the flame being then extinguished when the partial oxidation of the alcoholic vapours begins in the heated spout. This is a simple but imperfect arrangement. The following is Dr. Kenwood's description of a methyl alcohol lamp tried by him :—

"The lamp which I have had made for the purpose of my experiments is very similar to Prof. Robinson's (of Brunswick, U.S.A.); it consists of a well of from 1 to 2 litres capacity, into which methyl alcohol is placed, and a hollow cylinder fits firmly on to this—the top of the cylinder being brought to a short funnel so as to encourage a draught. In its lower part the cylinder is perforated for the free admission of air, and just above the perforated part and inside the cylinder a narrow shoulder projects, which is for the purpose of supporting a disc of extra hard-pressed asbestos millboard, perforated in many places, and platinized by soaking in a solution of platinic chloride in alcohol and then burning off the alcohol until platinum black results. In practice the requisite amount of alcohol in the well is first ignited, and then the top part of the lamp is removed and the flame extinguished by placing some object (as a lid) over it; when the top part of the lamp is replaced the alcohol vapours come away actively, mixed with the air drawn through the perforations, and in passing through the platinized asbestos set it in a red glow, which continues until all the alcohol has evaporated.

"It is most generally recommended that with these

[1] *Therapist*, Oct. 15th, 1901.

lamps about two litres of alcohol is sufficient for rooms of 3,000 cubic feet, and about six hours' exposure should be given. The cost for disinfecting an ordinary room would be about 2/6."

One of the most recent of these lamps, the "Formogène Richard," resembles the form used by Dr. Kenwood. It seems, however, difficult to ensure the conversion of the whole of the methyl alcohol into aldehyde, and the cost of the spirit is, therefore, somewhat high, as two quarts of spirit, costing about 10/- a gallon, are required for each charge. The Formogène Richard lamp has yielded good results in the hands of the late Dr. Kanthack, and Dr. Kenwood showed that when a very large quantity of methyl alcohol is used his lamp gave good results.

The objections to the use of the methyl alcohol lamps are that the oxidation of the methyl alcohol to formic aldehyde is far from complete, the rate of generation and amount of the gas varying considerably with the same apparatus in different hands, and also that quantities of poisonous carbon monoxide are evolved in the room equal to 3 to 5 per cent. of the alcohol used. It is satisfactory, however, to notice that Dr. Kenwood has found that sufficient formaldehyde can be generated from $1\frac{1}{2}$ litres of alcohol to disinfect a room of 2,000 cubic feet under the conditions stated.

The difficulties attending the direct production of formaldehyde from methyl alcohol *in situ* have led other investigators to endeavour to obviate the production of para-formaldehyde when using the formaldehyde solution. In America, the Chicago Board of Health have devised a special spray producer (Dr. Behm), and have, therefore, given up all attempts at using lamps. The Massachusetts State Board use a kind of autoclave, and this apparatus is now in use by many of the Boards of Health in the States, and, under the name of the Sanitary Formaldehyde Regenerator, has recently been introduced into this country. It resembles very closely Trillat's autoclave, and the formaldehyde is first mixed with calcium chloride solution, which is meant to facilitate the retention of the water when the gas is generated. It would seem, from my own experiments, that formaldehyde acts as a disinfectant in presence of some water vapour, and, therefore, care must be taken not to generate the gas too dry, whilst, on the other hand,

thorough penetration seems to be retarded when too much water is present.

Holzine is a 35 to 60 per cent. solution of formaldehyde in methyl alcohol, with 5 per cent. of menthol "to prevent formation of methylal." It is used in the Oppermann-Rosenberg apparatus, being evaporated from an asbestos plate by a few pieces of red-hot coke, and is also employed as a spray. K. Walter found that polymerization of the aldehyde was not prevented.[1] Krell's patent 23,886 of 1900, rapidly pouring formaldehyde solution into a vessel in which a sufficient mass of heated metal had been placed to evaporate the liquid, is open to the same objection of waste by polymerization.

Para-formaldehyde, or trioxymethylene ($C_3H_6O_3$), the white residue resulting from the evaporation of aqueous formaldehyde, is used, compressed into tabloids, under the name of "paraform" by the Formalin Hygienic Company

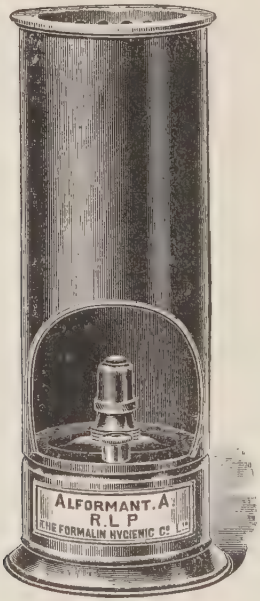


Fig. 19. The Alformant Lamp.

in their Alformant or "Schering" lamp. This is an ordinary spirit lamp with a large metal chimney supporting

[1] *Chem. Centralblatt*, 1896, ii., 119.

a perforated metal cup at about 4in. over the flame. Some "paraform" tablets, weighing about 1 gramme each, are placed in the cup, and the moist products of combustion from the spirit pass up through the perforations, when the para-formaldehyde is volatilized chiefly as active formaldehyde. The directions given are to use at least ten tablets or 10 grammes of para-formaldehyde, to every 1,000 cubic feet with six hours' exposure. The cost of material would be less than 1/- for ordinarily-sized rooms.

Dr. Kenwood succeeded in sterilizing swabs infected with B. diphtheriæ by using twenty-one paraform tablets in a room of 2,004 cubic feet with four hours' exposure.

The author has had considerable experience with the paraform lamps, and details of his experiments were published in *Public Health,* November, 1897. A room of 1,500 cubic feet, was first used to find the minimum quantity of para-formaldehyde which would disinfect, and it was found that

(*a*) 1 gramme per 1,000 cubic feet did not kill B. coli. communis when the room was sealed for four hours.

(*b*) Four grammes per 1,000 killed B. coli communis and Staph. pyog. aur. exposed on silk thread, but not when the cultures were soaked into paper slips, the room being sealed for six hours.

(*c*) With 8 grammes per 1,000 B. coli communis and Staph. pyog. aur. were killed on paper slips.

(*d*) Fifteen tablets per 1,500 cubic feet (10 grammes per 1,000) succeeded in killing B. coli communis, B. typhosus, B. diphtheriæ, Staph. pyog. aur., when the room was sealed for twenty hours and the organisms exposed on silk threads, paper slips, and inside rolls of linen which had been dipped into the cultures. B. anthracis and B. subtilis exposed in the same three ways were not killed in this experiment.

(*e*) Twenty tablets, equal to 13.3 grms. per 1,000, with B. anthracis and B. subtilis both containing spores, failed to sterilize the silk threads or paper slips when they were exposed in the centre of the room on the same level as the lamp, but the B. anthracis exposed on a linen slip near the wall was found to be sterile. Room sealed 20 hours.

(*f*) With 20 grammes per 1,000 cubic feet, silk threads infected with B. anthracis, and exposed (1) 6ft. over the lamp and (2) near the wall, were sterilized. A dry paper

slip similarly infected near the wall gave growths on sub-culture, but those from a wet slip were much attenuated and did not appear until the fourth day. An infected fold of dry linen similarly placed was not sterilized, but the organisms in another fold, wetted and then infected, were killed. Room sealed 24 hours.

In further experiments to determine whether it was necessary to remove infected fabrics from the room, in other words, to ascertain the penetrating power, I found that, with 10 grammes per 1,000 cubic feet, pieces of damp linen infected with Staph. pyog. aureus culture, and placed in test tubes plugged with cotton wool, were not sterilized when they had been enclosed within eight folds of a heavy blanket, and when buried in the centre of a feather pillow; on the other hand, when 13·3 grammes per 1,000 cubic feet were tried, infected linen sealed in a sterile paper envelope exposed on a table in the room was sterile, and the infected linen from similar envelopes placed inside the pillow and between eight folds of the blanket did not give any growth of the staphylococcus after sub-culture, although in the last two cases the broth of the sub-culture became turbid from some other adventitious organism. Room sealed 24 hours.

In the above experiments I obtained sufficient good results with 10 grammes per 1,000 cubic feet to warrant this quantity being used in all cases of ordinary disinfection, and if in special cases the walls and floors are in addition sprayed with a 0·5 per cent. formalin solution before using the lamp, I believe that disinfection would be ensured.

In a report to the London County Council dated February 10th, 1902, on their experiments with paraform lamps, using 20 grammes of the tablets per 1,000 cubic feet for 5 hours, Drs. Klein, Houston and Gordon state that "in cases where wood flooring, unpainted or unvarnished articles of furniture, or similar absorbing materials and cloth fabrics are to be submitted to disinfection on account of their being possibly polluted with tubercular sputum, or highly resisting microbes like the spores of anthrax or other spores (*e.g.* tetanus), the disinfection with formalin alone [in the method mentioned] will not suffice." It will be noticed that the time is not even that given in the directions for the use of the lamp in ordinary cases.

Allan and Cribb's comparative trials with sulphur

"candles" and with the alformant lamp led them to the conclusions that (1) sulphur dioxide will kill B. diphtheriæ either in a moist or dry state, but is not to be relied on for typhoid or for more resisting organisms, (2) formaldehyde will kill diphtheria and typhoid organisms in either a moist or dry condition, and several other organisms, including Staph. pyog. aureus, in a moist state, and has the advantage over sulphur dioxide that it diffuses better and does not affect colours or metals.[1]

To disinfect goods like books and boots, which were liable to be injured by steam, Dr. Charles Porter, at Stockport, placed them with an alformant lamp containing five tablets in the chest of a "Nottingham" steam disinfector of 200 cub. ft. capacity. Dr. Symons, of Bath, used, either in spray or liquid form, 3 to 6 oz. formalin followed by 2 oz. water, in a steam disinfector of 70 cub. ft., from which about two-thirds of the air had been exhausted, closing for at least one hour, then exhausting partially again and passing in 1 oz. of liqu. ammoniæ a short time before opening.[2]

Most of these lamps relied upon the water obtained in the combustion of the spirit used for heating the solid paraform, for supplying the necessary amount of moisture, but methylated spirit gives somewhat too small a quantity for the best results. This defect has been remedied in what is called the Hydroformant lamp, in which an annular vessel holding 12 ozs. of water is fixed, and this water is converted into steam at the same time as the tablets are gasified. A somewhat more cumbersome apparatus known as Flugge's embodies the same idea, and is used largely in Germany. In connection with this apparatus, a second generator is employed, which is used for passing ammonia into the room seven or eight hours after the development of the formaldehyde, the ammonia combining with the latter to form hexamethylene tetramine, which is free from odour, before the room is opened.

Dr. Ascoli[3] made a chemico-biological study of formaldehyde as a disinfectant, and reported very favourably on

[1] *Brit. Med. J.*, Aug. 13th, 1898.

[2] *J. San. Inst.*, Jan., 1900, p. 675.

[3] *Giornale de R. Soc. d'Igiene*, No. 7, Milan, 1894.

the solutions in surgery, and on vapours from the tablets in disinfecting clothes, etc. Schepilewsky[1] also speaks favourably. He says that the vapour shows a greater disinfecting power than the solution, and he found moisture and heat conducive to good results.

Strüver[2] estimates the formaldehyde vapours from the lamp by drawing an aliquot portion of the air from the chamber through a series of wash-bottles containing water, using ammonia and silver nitrate in the last bottle as an indicator. He then adds excess of ammonia to the aqueous solutions of the gas, and titrates back with oxalic acid.

Dr. Aronson,[3] using sixty-six grammes to 1,000 cubic feet caused the death of the tubercle bacillus immersed under several millimetres of broth, and anthrax spores exposed on gauze. Using thirty-three tablets per 1000 cubic feet, he succeeded in killing B. pyocyaneus, staphylococcus, typhoid, and diphtheria bacilli, but not anthrax spores, in every case.

Prof. Grawitz considers 1·5—2 grammes per cubic metre (45—60 per 1000 cubic feet) sufficient in all cases except bed-linen, etc., which he still disinfects with steam. The city hospital at Charlottenburg is now disinfected in this way.

Harrington[4] states that the gas penetrates through dry pervious fabrics, but not always sufficiently to ensure germicidal action, and that when the fabrics are damp there is practically no penetration—see my results (*f*), p. 309. He concludes that formaldehyde should only be resorted to for surface disinfection. Inasmuch as the vapour is so soluble in water one would expect that materials previously moistened would absorb more of the gas than dry fabrics, and therefore show greater efficiency, as I found in my experiments.

E. M. Parks, in comparative trials at New York with five varieties of fumigation apparatus, found formaldehyde much better and less destructive than sulphur.[5]

[1] *Centralbl. f. Bakter.*, 19 [1], 794. [2] *Zeits. f. Hyg*, 1897, xxv., 357.

[3] *Therapist*, May, 1897, 52. [4] *Amer. J Med. Sc.*

[5] *Journ. Massachusetts Assoc. of Boards of Health*, March, 1898. See also Dr. Brough's paper in the same number, p. 44, and the ensuing discussion, in which the president mentioned a remarkable instance of success with formalin as a deodorant. A favourable report on the use of formaldehyde in Chicago is also given in the Monthly Bulletin of the Health Department of that city, May, 1899. See also a detailed report by Prof. Robinson to the Maine State Board of Health, 1899.

At the Bowdoin College, U.S.A., Dr. Whittier[1] uses a special form of vaporizer, apparently without any water bath, and with kerosene as a source of heat. With this apparatus he has been successful in destroying B. coli communis and B. subtilis from 48 hours agar slants, when using ½ kilo. of formalin per 1000 cub. ft., but he found that the tubercle bacillus was more resistant than these. This quantity is much in excess of that found by the author to be necessary when working with the Thursfield apparatus (p. 316) properly jacketed with the requisite quantity of water.

Doty, in the *New York Medical Journal*, October 16th, 1897, states that with an alformant lamp, using 40 gramme-pastilles per 1000 cubic feet, during a period of twelve hours, he failed to kill germs when wrapped in folds of newspapers; and Wynter Blyth, more recently, has also obtained unsatisfactory results. It would seem, however, from these experiments that, assuming the room was properly sealed, the rate of burning the spirit in the lamp could not have been properly adjusted, so as to ensure the conversion of the paraform into formaldehyde. Dry heat causes a distillation of the paraform unchanged, and this can be easily detected by the comparative absence of the smell of formaldehyde when the room is opened after disinfection.

Trillat, in a paper read before the Society of French Chemists in 1895, observes that "the odour of formalin proved a good criterion of its penetrating action. Floors, carpets, papers, and even the plaster of the walls were impregnated. A piece of wood disinfected in this manner, when placed under a bell-jar, disengaged a considerable quantity of formalin gas." He remarks that the deodorant properties are mainly due to combination with sulphuretted and ammoniacal products of decomposition.[2]

Roberge's Apparatus.—A metallic cylinder, containing trioxymethylene in the proportion of 1 gramme per cubic metre of room space, is furnished with a narrow inlet tube, admitting air from an outlet to a pump. The cylinder can be placed in the centre of an annular boiler containing water boiling under pressure at 150° C. At this temperature the trioxymethylene is resolved into formaldehyde vapour.

[1] *San. Record*, 1900, p. 537.

[2] *Ann. de l'Inst. Pasteur*, x., 283 and 299.

The steam is admitted to the pump, and the mixture of steam, formaldehyde, and a small quantity of air, passes at three atmospheres pressure to the chamber to be disinfected. Dr. Trétrop, reporting on this apparatus, states that the injection occupied ten minutes; he used 50 grammes of trioxymethylene for a space of 50 metres (= 28·3 grammes per 1,000 cubic feet), and allowed the room to remain sealed for eighteen hours, the temperature being 18° C. Active cultures of pyocyaneus, typhosus, staphylococcus citreus (croup), and spore-bearing anthrax, exposed, both dry and moist, on paper and linen, were all completely sterilized. Moulds, however, remained unaffected. He commends the apparatus for *surface disinfection*, and considers that this is the utmost that is attainable by any gas.

Nils Englund, at the Stockholm Hygienic Institute,[1] recommends two methods which he found efficient for the destruction of bacteria in rooms.

(1) Walls and furniture are thoroughly sprayed with 2 per cent. formaldehyde and the room closed for twenty-four hours. "60 to 70 c.c. sufficed for each square metre of surface."

(2) Cloths saturated with one pint formalin solution in which ½ lb. of calcium chloride was dissolved were hung in the closed room for twenty-four hours. This effected the sterilization of furs and books. In default of a vapour apparatus the suggestion seems valuable.

K. Walter made a series of observations in the Research Department of the 10th German Army Corps on the strength of formaldehyde solutions which was fatal to common forms of pathogenic bacteria. "With anthrax, cholera, typhoid, staphylococcus, and diphtheria 1 in 10,000 arrested growth, and slightly stronger solutions sufficed to destroy. Fæces were deodorized and rendered aseptic by a 10 per cent. solution in ten minutes."[2] With regard to the vapour, although he concludes that it acts efficiently as a disinfectant on germs near the surface, he failed to secure sterilization of those more deeply situated.[3] Remarking that "steam in motion is more efficacious in penetrating objects than steam not in motion," in later experiments he passed formaldehyde

[1] *Hyg. Rundschau*, 1896, 369.
[2] *Zeits. f. Hyg.*, xxi., 421.
[3] *Chem. Centralblatt*, 1896, ii., 119.

vapour together with steam under pressure through a cylinder 130 centimetres long and 0·5 metre high, containing the articles to be disinfected; by this method it was found that the formaldehyde penetrated to the interior. The mixed vapours were afterwards condensed, giving a solution adapted for washing floors and walls. He is still of opinion that the disinfection of a room and its entire contents *in one action* cannot be carried out by the vapour, "no matter by what method it is evolved, but that dresses, uniforms, and the like may be disinfected entirely and without injury by means of a current of formaldehyde vapour."[1]

In my own experiments I had already remarked the superior energy of a current and of moisture (see experiments *e*, *f*, and *g*, p. 309), bearing in mind that the convection current passes up from the lamp and down the walls; in fact, one of the advantages I have indicated for formaldehyde is its ready diffusibility and solubility in water, so that if the room is properly sealed it is only a question of time and quantity when the formaldehyde shall have completely diffused through the air and impregnated all the moisture in the chamber. These experimental details are conditions of every species of disinfection: they are easily attained but not often observed. I have mentioned on p. 310 the quantities and times that I found successful in practice even with the more resistant organisms. At the same time if the fabrics are considerable in number and volume, since the surfaces absorb a correspondingly greater amount of vapour, it will be necessary to employ a larger quantity of the reagent (experiment *g*), or it may be even desirable to specially disinfect them in an apparatus such as Walter recommends.[2]

For local application an addition of glycerine seems to present advantages, on account of its remaining moist, and therefore penetrating porous materials and retaining the formalin, in addition to its own antiseptic power. R. Walther and A. Schlossman in experiments with Lingner's apparatus, by which a mixture of 75 formalin (40 per cent.), 15 water and 10 glycerine, called "glycoformal," can be

[1] *Zeits. f. Hyg.*, xxvi., 454-475; *Chem. Centr.*, 1898, i. [6]. 306; *Journ. Soc. Chem. Ind.*, April 30th, 1898.

[2] *Münch. Med. Wochenschr.*, 1899, xlvi., 1535.

sprayed into a room until a thick fog results, using about 4lb. of mixture per 1,000 cubic feet (= 544 grm. CH_2O, or 1·4 per cent. in the air), and closing merely in the ordinary manner, reported that they succeeded in sterilizing a number of objects of the most refractory character and of considerable thicknesses, while live animals were not injured.[1]

Lingner's apparatus has been much used in Germany and has lately been introduced into this country. Klein's report of April, 1902, states that "three hours' exposure to formaldehyde in a sealed up room with the Lingner apparatus was successful in completely disinfecting virulent spores of B. anthracis and virulent tubercular sputum." Comparative experiments with different apparatus that have been published by Koch,[2] Escherich and Dzierzgovsky[3] give the preference to this process. According to the last-named, the Walther-Schlossmann method with Lingner's apparatus effected complete extinction of the plague in Astrachan in 1899.[4] (Fig. 18, p. 302).

The addition of quicklime has been suggested for evolving formaldehyde from its solution, but in experiments with this dehydrating agent I have obtained only 8 per cent. of the theoretical yield, so that the heat evolved by the union of the lime with the water is sufficient to polymerize a large quantity of the gas. Fused calcium chloride and concentrated sulphuric acid also gave very little gas. When lime is added to the formaldehyde solution, calcium formate is produced, and probably, therefore, some methyl alcohol, according to the equation :—

$$2\,CH_2O + H_2O = CH_3OH + H.COOH$$

Thursfield's improved Formaldehyde Disinfector (fig. 20) consists of a steam generator A, containing an annular vessel for vaporizing the formaldehyde solution; the necessary quantity of water is fed through the hole B, which also acts as a safety valve. The formalin is added through the chamber C, which is closed by a blast-pipe D, through which the steam and formaldehyde vapour escape. A thorough mixing of the steam and formaldehyde takes place in the chamber C, and any desired ratio of water to

[1] *Journ. prakt. Chem.*, lvii., 173 and 512.
[2] *Deutsch Med. Wochenschr.*, Nov. 17th, 1898.
[3] *Wratsch*, St Petersburg, No. 1 and 2, 1899.
[4] *J. Russian Soc. for protect. of Nat. Health*, No. 2 and 3, 1900, 179.

formalin can be employed, while the quantity volatilized can be further regulated by varying the amount of spirit burnt in the spirit lamp F. In order to confirm the necessity of larger quantities of formaldehyde to ensure the destruction of spores, I carried out a series of experiments using the

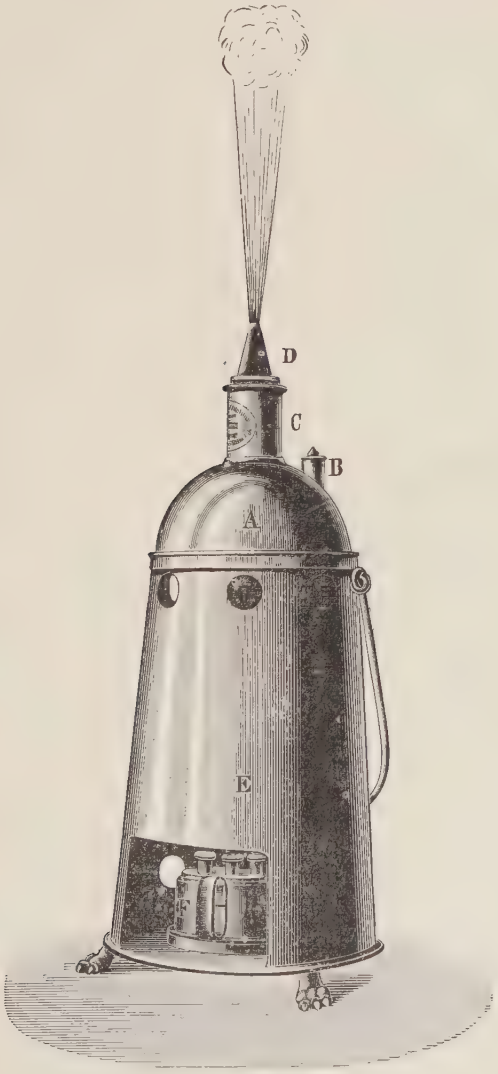


FIG. 20. THURSFIELD GENERATOR.

Thursfield apparatus,[1] and obtained very satisfactory results with anthrax spores. The general conclusions arrived at

[1] Sanitary Institute Congress, 1902; *Journ. San. Inst.*, Jan. 1903, p. 508

were: (1) 7·5 c.c. of 40 per cent. formaldehyde solution per cubic metre ($35\frac{1}{3}$ cubic feet) when vaporized with not less than four times its volume of water, excluding the steam derived from the spirit, was sufficient for killing resistant spores of the anthrax type; (2) the disinfectant had little penetrating power, especially through wet material; (3) the time of contact need not exceed a period of six hours.

Dr. Max Gruber, of Vienna, in 1902, showed that anthrax spores (whose resistance was proved by control cultures being alive after 14 to 20 days in 5 per cent. carbolic acid), when dried on silk threads enclosed in capsules of filter paper and distributed in a room at 18° C., were killed by the Thursfield disinfector in seven hours.

The Thursfield figure given above ($7\frac{1}{2}$ c.c. of formalin per cub. metre) is equal to 85 grms. of formaldehyde gas per 1000 cub. ft., or 0·225 per cent. by volume in the air. This is $4\frac{1}{4}$ times the maximum used in my paraform lamp experiments just quoted (20 grms. per 1000 cub. ft., or about 0·05 per cent. by volume), but is about half that used in Trillat's Autoclave, and less than one-sixth the amount in the Lingner process according to Walther.

Among the large number of formaldehyde patents are the Geneste-Herscher generator (No. 21,074 of 1901), with a special measuring arrangement, the Sanitas Fumigator,[1] Sharratt's Regenerator, and the Shpreotz Sprayer.[2]

As an antiseptic F. J. Bird's experiments showed that formaldehyde vapour was more effective than the solution.[3] The same author gives a table of the purposes for which the agent in solution has been employed and the proportions recommended.[4] M. Trétrop[5] sets high value on the solution in surgery. It is largely used in museums for hardening and preserving preparations. In Germany Kieselguhr tablets saturated with formaldehyde are used for placing in coffins to preserve and deodorise bodies, especially in cases of inquests. The solution is now official in the German Pharmacopœia.

Dr. Reik[6] has investigated the sterilization of surgical instruments by exposing them to the vapours from an

[1] *Public Health*, Dec., 1901.
[2] *Therapist*, April 15th, 1901.
[3] *British Pharm. Conf.*, July. 1896.
[4] *Pharm. Journ.*, [4], iii., 269.
[5] *Bull. Gén. de Thérap.*, cxxxi., 376.
[6] *Hospital*, May, 1898.

Alformant lamp sealed in a small cupboard. He claims that by this means the instruments are in no way injured, and can be used at once without requiring any drying, etc., as in the case when they have been treated with a liquid disinfectant.

Holbau and Hlawacek sterilize surgical catgut by soaking in 2 to 4 per cent. formaldehyde for twelve hours, then boiling in water for half an hour, and finally dipping in alcoholic solution of mercuric chloride.[1] It is a question whether after such heroic treatment the mercurial solution would be necessary.

Guy's Hospital Gazette, October 26th, 1896, states on the authority of Mr. Alfred Salter, that *Tricophyton tonsurans,* the fungus of ringworm, is quickly killed by formaldehyde. See also Abba and Rondelli, *Zeit. f. Hygiene,* xxvii., 1., 1898, p. 49; Fairbanks and Grawitz, *Cent. f. Bakt.,* 1898, pp. 20, 80, 138, and 689; Schultz, *loc. cit.,* 1898, p. 594; V. Esmarch and Zweigert, *Deutsch Vierteljahrsschr. f. offentl. Gesundheitsplege,* 1898, p. 156.

Under the name of *triformol,* trioxymethylene has been introduced as an intestinal antiseptic. It is a light, white substance, soluble in boiling water, and in alkalies. It is stated to be as active an antiseptic as β-naphthol. In large doses of 3 to 4 grammes it has a purgative action, but in small doses it produces constipation.[2]

Among antiseptic preparations containing formaldehyde are:—

Glutol.—Dr. Schleich[3] has shown that the condensation product of formaldehyde and gelatine can be powdered and used in this form as an antiseptic for wounds. Glutol may be prepared by exposing a solution of gelatine to formaldehyde vapour, or by adding a small quantity of formalin to the gelatine solution, and subsequent drying and powdering —the powder should be kept in formaldehyde vapour. It is a stable substance, insoluble in water and ordinary reagents, unaffected by moderate heat, and in its original state possesses no antiseptic value, so that administered internally it is without effect, but when applied to a wound the gelatine-formaldehyde slowly dissociates and the antiseptic is regenerated *in situ.* A. Gottstein has also shown

[1] *Therap. Monatschrift,* March, 1896.
[2] *L'Union Pharm.,* xxxvi., 534, after *Schw. Woch. fur chim. pharm.*
[3] *Therapist,* March, 1896.

that in old wounds, where it is difficult to bring the powder into contact with the unhealthy tissue, the difficulty can be overcome by moistening the wound, after well dusting with powder, with a hydrochloric acid solution of pepsin (pepsin 75 grains, HCl 5 minims, aq. dest. 4 oz.), as this dissolves the crust and effects the decomposition of the gelatine-formaldehyde compound, thus ensuring the evolution of formaldehyde vapour.

Amyloform (Claasen) is described as an inodorous and insoluble compound of formaldehyde and starch, showing no structure under the microscope, and not decomposed at 110° C., therefore susceptible of sterilization. It is recommended as an antiseptic for wounds.

Iodoformin[1] is stated to be a tetriodo-hexamethylene-tetramine, $C_6H_{12}N_4I_4$, containing 80 per cent. of iodine (Trillat and Limousin) obtained by the action of ammonia and then of iodine on formaldehyde. It is an almost inodorous powder decomposed by acids and alkalies, or by heating to 178° C., and affected by light; insoluble in water, but can be emulsified with glycerine. It is claimed that iodine and formaldehyde are only liberated in the wound, and that the objectionable odour of iodoform is thus as far as possible avoided.

Iod-Iodoform is another preparation containing 40 per cent. of iodoformin and 50 per cent. of free iodine.

Eka-Iodoform is a pure iodoform prepared by electrolysis and sterilized by paraform. It is recommended in the place of glutol for irregular excavated wounds.[2]

Iodoformin-Mercury is described as containing about 20 per cent. of mercury and 50 per cent. of iodoform.

Iodo-ethylformin, $C_6H_{12}N_4(C_2H_5I)_2$, so-called "iodoformal,"[3] is prepared by the action of ethyl iodide on a weak alcoholic solution of hexamethylene-tetramine. It is soluble in water and alcohol, insoluble in ether and chloroform, and decomposed by strong acids and by sodium carbonate.[4] "Iodothymoform" is a crystalline compound described as

[1] *Therap. Monatschr.*, 1895, ix.; *Deutsche Med. Wochenschrifte*; 36 and 50; *Allgemeine Med. Centralzeitung*, 1896, 23; and Professor Kolliker's Lecture, Chirurg. Congress, Berlin.

[2] Thomalla, *Therap. Monatshefte*, July, 1897.

[3] *Méd. nouv.*, 1897.

[4] *Pharm. Centr.* xxxviii., 457; *Journ. Soc. Chem. Ind.*, September 30th, 1897.

"a new disinfectant."[1] "Eugenoform" is a sodium compound of eugenol-carbinol (obtained by the action of formaldehyde on eugenol, p. 283), and is said by Vogel to be a powerful disinfectant of the digestive tract in doses of 0·5 to 1 gramme.[2] A compound of urea with formaldehyde is the basis of several preparations.[3]

Steriform and Sterisol[4] are preparations by P. Rosenberg containing milk-sugar and formaldehyde.

Alcohol, $C_2H_5(OH)$, coagulates albumen, hardens animal tissues and renders them imputrescible, hence it is used for preserving anatomical specimens, bodies, etc. For this purpose the old form of "methylated spirit," containing 10 per cent. of crude wood spirit, is better and cheaper. The new form, mixed with petroleum, is not available, as it becomes turbid with water; for other antiseptic purposes, however, it is equally serviceable.

Bucholtz observed that a 1 in 30 solution of alcohol did not prevent the development of vibrios.[5] Calvert and M'Dougall found that 1 in 20 prevented the putrefaction of beef-juice and egg-albumen for six days. Wernitz proved that 1 in 3 to 1 in 10 destroyed the activity of non-organized ferments (ptyalin, etc.).[6] Jalan de la Croix[7] found that it required a solution of 1 in 21 to prevent the growth of adult bacteria transferred into bouillon, but the organisms were not killed below 1 in 4·4, or 23 per cent., and the germs not below 1 in 1·18, or 85 per cent. Meat broth freely exposed to air remained free from bacteria when the proportion was 1 in 11. Gosselin and Bergeron[8] exposed fresh blood in vessels covered with folds of muslin to the vapour of strong spirit under a bell-jar. Putrefaction was deferred to the eighth day by six drops of alcohol, whereas naturally it would have appeared on the third or fourth day. Miquel's statement is that "95 parts of alcohol neutralized 1 litre of beef tea," about 10 per cent.[9]

It has been suggested that the gradual re-appearance of

[1] *Pharm. Journ.*, 1899, lxii, 360.
[2] *Year Book of Pharm.*, 1899, 226.
[3] *Z oest. Apoth. Ver.*, 1898, 410.
[4] *Zeits. f. Hyg.*, 1897, xxiv., 488; *Zeits. oesterr. Apoth. Ver.*, xxxiv., 733; also see Burghardt and Karewski, *Trans. Ver. Med., Berlin*, 1897; and *Südd. Apoth. Zeit.*, 1897, 40.
[5] *Archiv. f. exp. Pathol.*, 1875, p. 159.
[6] *Wirkung der Antiseptica*, 1880.
[7] *Archiv. f. exp. Pathol.*, 1881, p. 175.
[8] *Arch. de Méd.*, 1881, p. 16.
[9] *Org. viv. de l'Atmosph.*, 1883, p. 289.

bacteria when the solutions are exposed to air is due to the loss of strength by evaporation of the alcohol. But Geissler has disproved this, finding that open tubes containing a mixture of water and alcohol, at the end of seventy-two hours still contained 32 per cent. of alcohol, the original amount having been 33 per cent. So that, as with other antiseptics, the bacteria have the power of slowly becoming accustomed to their environment.[1] With alcohol this toleration appears to be very marked.

It is well known that strong alcohol, from its somewhat oily nature, exhibits some delay in mixing with water and does not readily penetrate wet surfaces, while if these are coagulated by it, as in the case of albuminous and gummy membranes, they exhibit a high resistance in proportion to the strength of the spirit. Dr. Epstein observed[2] that although alcohol in 50 per cent. dilution had some bactericidal power, weaker and stronger solutions alike were feebler, and absolute alcohol or 90 per cent. dilutions and upwards were quite inert; while even the stronger antiseptics in alcoholic solutions were almost inert. These statements have been confirmed by many observers. Dr. Minervini, at Genoa, working with silk threads, found that cold alcohol of the dilutions indicated required the following times for killing various bacteria:—

	Degree of Dilution.				
	25 per cent.	50 per cent.	70 per cent.	80 per cent.	99 per cent.
M. tetragenus	over 1 hr.	30 min.	30 min.	1 to 6 hrs.	
B. pyocyaneus... ...	under 1 hr.	10 min.	10 min.	6 hrs.	12 hrs.
M. prodigiosus ...	1 hr.	30 min.	10 min.	6 hrs.	12-24 hrs.
Staphylococcus pyog. aureus	12-24 hrs.	10 min.	10 min.	living after 3 days.	
B. coli	24 hrs.	1 hr.	1 hr.	living after 24 hrs.	
B. subtilis	all living after 8 days.				
B. anthracis	all living after 50 days.				

Three per cent. solutions of carbolic acid in 25, 80 and 99 per cent. alcohol had no effect on the sporiferous bacilli in 3 days, and only an uncertain action on the others in one hour; but in 50 to 70 per cent. dilutions, B. pyocyaneus was killed in 75 minutes, M. tetragenus in 30, M. prodigiosus, S. pyog. aureus, and B. coli in one hour. One of sublimate in 1,000 of water or of 25 per cent. alcohol, killed spore-

[1] See *Salicylic acid*, p. 272; Watson Cheyne, *Med. Times and Gaz.*, 1879, p. 561.
[2] *Zeits. f. Hyg.*, 1897, 1.

bearing bacteria in 10 to 15, and non-spore-bearing in 5 minutes. In 80 to 99 per cent. the non-sporiferous were often still living after 30 minutes, and the sporiferous always so after 24 hours. Silver nitrate solutions behaved similarly.[1] Bertarelli,[2] and Weigl,[3] extended and corroborated these results. Goenner failed to disinfect the hands with alcohol: cultures taken from the skin or from beneath the nails, after cleansing with various strengths of alcohol, gave rise to cocci and various organisms. Harrington and Walker[4] find that dry bacteria are not killed by strong alcohol, but when moist any strength above 40 per cent. is effective in 5 minutes against the commoner non-sporing pathogenic species. Sixty to seventy per cent. may be depended upon usually, but not always. As to the dilute spirit, Wirgin[5] found that while even 0·1 per cent. alcohol hindered the development of some bacteria, most kinds could grow in strengths up to 6·5, and some up to 7, 8 and 8·5 per cent., while 10 per cent. stopped the growth.

As to the effect of alcohol vapour, A. Petit at Versailles, in 1894, suggested its use for preserving fruit, finding that grapes, when laid in a cemented-brick chamber in which an open vessel of alcohol was placed, after two months had not changed in appearance or quality, while others, without the alcohol, became rotten and mouldy under 20 days.[6] Seige[7] observed that the destructive action of alcohol vapours towards spores is never so rapid as that of steam in motion at 100° C. The effect decreases with increasing proportions of alcohol till it becomes practically *nil*, for the same reasons as with solutions. He concludes that the suggested use of alcohol with steam in disinfecting objects infected with anthrax is not advisable.

Alcohol, therefore, in itself is seldom reliable as an antiseptic, and still less as a disinfectant, although it has been used for washing open wounds and even cavities. Here of course its absorption and stimulant action must be taken into account. With alcoholic solutions of essential oils, etc., the latter are often present in such small quantity that the preparations act only as scents.

[1] *Arch. f. Hyg.*, xxxiv., 2.
[2] *Il Policlinico*, 1900; *Rev. d'Hyg.*, Jan., 1901.
[3] *Archiv f. Hyg.*, xliv., 273.
[4] *Boston Med. Journ.*, May 21st, 1903.
[5] *Chem. Centr.*, 1903, i., 50; *Journ. Soc. Chem. Ind.*, 1903, 159.
[6] *Journ. Soc. Chem. Ind.*, 1895, 880.
[7] *Chem. Centr.*, 1902, 1 [2], 130.

Dr. J. J. Ridge[1] describes the effect of minute quantities of alcohol on cell protoplasm, and points out that it causes a shrinkage by withdrawing water, slowly hardens and thickens the walls and hinders nutrition.[2] To these phenomena must be attributed whatever inhibitory action it possesses. Minute quantities have no action in preventing putrefaction. Wines, for example, if of weak alcoholic strength, become sour, and even putrid. A mixture of acetic ether and alcohol, with or without acetic acid, was patented as an antiseptic called "Salubrine."[3]

Formic Acid, H.CO.OH resembles its homologue acetic acid. Its antiseptic power seems to be rather higher, in proportion to the saturating power of the two acids for bases (inversely as the molecular weights, 46 and 60; see *ante*, p. 213), athough Kitasato made acetic slightly stronger in nutrient media, stating that with *B. typhosus* the amounts per cent. in cases of (1) growth, (2) growth restrained, (3) no growth, were respectively: formic acid, 0·22, 0·278, and 0·356; acetic acid, 0·2, 0·225, and 0·3; with *Sp. choleræ*, formic 0·11, 0·167, 0·22, acetic, 0·1, 0·153, 0·2. I have found that in distilled water B. typhosus is killed by 0·5 per cent. of formic acid in less than 15, and by 0·1 per cent. in about 30 minutes. Sodium formate, H.COONa, is a soluble salt resembling the acetate, but possessing reducing properties; it has the advantage of dissolving many compounds which are sparingly soluble in water alone, such as arsenious, boric, and salicylic acids, and it does not favour the growth of moulds like sodium acetate; consequently it has been incidentally mentioned in several patents, as, for example, No. 3,153, 1882, "Boric acid melted with sodium phosphate and formate, can be cast into homogeneous solid cakes, which are inodorous, very soluble and almost tasteless; to be used by dipping or soaking to preserve provisions." It would leave a white efflorescent crust, which would undoubtedly be antiseptic, and could easily be washed off.

Acetic Acid, $CH_3.CO.OH$, in the pure state or "glacial," is a crystalline solid melting at 17°, and boiling at 118° C.; specific gravity 1·055. It has a strong pungent odour, and is very caustic. The "strong acetic acid" of

[1] *Brit. Medical Association*, 1890.
[2] *Brit Med. Journ.*, vol. i., 1891.
[3] No. 10,465, 1893; *Journ. Soc. Chem. Ind.*, 1894, p. 898.

the *British Pharmacopœia* contains about 30 per cent. of real acid; vinegar from 3 to 5 per cent.

A more or less concentrated acid, scented with spices, was much used in the middle ages under the name of "aromatic vinegar," to drive away plague. Glacial acetic acid dissolves considerable quantities of camphor and essential oils, and does not wholly deposit them on dilution.

Acetic acid is the chief product of the action of *Mycoderma aceti* on alcohol. When it has reached a certain amount, it checks and finally stops this fermentation, and, if sufficiently strong, it inhibits the growth of all bacteria, hence its use for pickles, etc. But, as is well known, if the vinegar be weak, it turns cloudy, and itself undergoes a putrefactive change. The influence of vinegar on organisms is, therefore, only a question of degree; inasmuch as most of them thrive best in a neutral or alkaline medium, any acid whatever will act as a restrainer of their growth (see *Hydrochloric* and *Sulphuric acids*, pp. 96 and 136). Calvert and M'Dougall say that 10 per cent. of acetic acid was necessary "to prevent animalcules in beef-juice and egg-albumen for six days. The effect of 10 per cent. on animalcules in already putrid beef-juice was none." Liebig defended the popular opinion by pointing out that it fixed ammonia and the organic bases accompanying fermentation.[1] That vinegar can be a bactericide is proved not only by the experiments given under formic acid but by the following: In July, 1903, I added B. coli communis to a good table vinegar (5.3 per cent. acetic strength), and to the same diluted to twice and to 10 and 50 times its volume with distilled water. In the two weaker liquids the bacillus was alive after 40 minutes, in the half strength it was killed in 15, and in the undiluted vinegar in 5 minutes.

"Aromatic vinegar," diluted with water, is frequently used to bathe the bodies of patients in typhoid fever and scarlatina; it certainly assists desquamation, acts as a cooling tonic to the skin, and removes or hides any offensive odours. It lends itself admirably to mixing with resorcin or a sulphocarbolate (p. 211); so yielding a powerful and efficient antiseptic. The acetates are not antiseptic.

Acetyl Peroxide $(C_2H_3O)_2O_2$ is an oily explosive

[1] Vallin, *Désinfectants*, p. 155.

liquid, slowly soluble in water and strongly oxidizing. Freer and Novy[1] state that both this and benzoyl-acetyl peroxide, in solutions containing 0·005 to 0·01 per cent. of active oxygen (= ·037 to ·074 per cent. of acetyl peroxide), destroyed all known disease-producing bacteria, including spores of B. mesentericus (which were not killed by 5 per cent phenol) within a minute, while a hydrogen peroxide solution containing 0·05 per cent. of active oxygen was without action on many bacteria even in 60 minutes. Benzoyl peroxide had no oxidizing action and was without effect on bacteria. A solution containing acetyl peroxide has been introduced under the name of "acetozone."

Pyroligneous Acid, or wood vinegar, is used in curing hams and fish. It owes its undoubted antiseptic power chiefly to the creosote it contains, but smoked hams are now said to owe their keeping qualities to the action of the formaldehyde vapour present in the smoke. "Kocide" is a recently introduced mixture of acetic acid and "creosote," the latter term itself implying a mixture of phenol, cresol, guaiacol and creasol.

Propionic acid, C_2H_5COOH, has been tested by Duggan on *B. subtilis*.[2] See *ante*, p. 213. Butyric acid in the proportion of 0·1 per cent., according to Dr. A. C. Jordan,[3] in broth tubes inoculated with vigorous B. coli. communis or B. typhosus, caused them to remain sterile; Staph. pyog. aureus required 0·2 per cent. Valerianic acid, C_4H_9COOH, mixed or combined with creosote, has been introduced as an internal antiseptic under the name of "Geosote." It has not the burning taste or causticity of creosote, but is a much weaker antiseptic.

Glycerine, $C_3H_5(OH)_3$, is a colourless, inodorous, and neutral syrup, sp. gr. 1·27, almost non-volatile at ordinary temperatures, boiling with partial decomposition at 290° C. It is miscible with water and alcohol, and dissolves a large number of salts and organic compounds. Strong solutions are antiseptic, but weaker ones can themselves undergo fermentation by the action of various bacteria (including B.

[1] *Amer. Chem. Journ.*, 1902, xxvii., [3], 161.

[2] *Ibid*, vol. vii., p. 62.

[3] *Practitioner*, September, 1902, p. 297; an experimental paper on the action of certain organic acids on the intestines, bearing on the treatment of diarrhœa.

pyocyaneus), producing ethyl alcohol or butyric products. Among its uses are the following :—

1. As it is sweet, almost unchangeable, and somewhat antiseptic it has been largely used for sweetening wines, temperance drinks (*e.g.*, "Hygeia"), syrups, artificial cordials, and "British wines," and for the preservation of beef-juice extracts. On this subject Lehmann remarks[1]: "An addition of glycerine, as it can be practically applied, should not be pronounced hurtful, for, even if large quantities of glycerine taken at once act as a purgative (say 15 to 30 grammes), and if very large quantities have an action resembling that of alcohol, there is no doubt that the addition of a few grammes of glycerine (5 grammes per litre) is perfectly harmless in such dilution. Experiments on the guinea-pig, a very susceptible animal, prove ½ gramme daily per kilogramme of body weight can be mixed with food without injury." Miquel[2] says that to prevent putrefaction of bouillon it is necessary to add 225 grammes of glycerine of specific gravity 1·25 to a litre—a very large dose, which implies that an amount to preserve food would also confer a penetrating and unpleasant sweetness. It has also been employed instead of sugar in beverages for diabetic patients, but causes purgative and griping effects. No prosecution is recorded under the Food and Drugs Acts.

2. In surgery, *to keep the skin pliable*. Undiluted it is irritant, and it does not maintain the surface moist, as, being very hygroscopic, it acts as a drier; on this account its habitual use for the hands or face makes the skin transparent, thin, and wrinkled. Bacteria and insects are killed by undiluted glycerine, since, having very low diffusive power, it causes death by desiccation. Spores, with thicker envelopes, resist it indefinitely, and on dilution commence growing rapidly.

3. As a medium for other medicaments, which it keeps liquid and allows to readily diffuse. "Glycerine of carbolic acid" has been commonly substituted for carbolic oil since Koch proved that phenol lost its power as a disinfectant when mixed with oil or absolute alcohol. O. von Wanscheim has, however, shown that although commercial

[1] *Hygiene*, 1893, vol. xi., p. 247.

[2] *Org. vivants*, chapter 9.

glycerine exerts a certain bactericidal influence on Staphylococcus pyogenes aureus and B. coli, acids, phenoloids and formaldehyde have less disinfecting power in glycerine than in aqueous solution. Hydrochloric acid and acetone are exceptions, their activity being increased by glycerine: the enfeebling effect in the other cases is also lessened progressively by the addition of water.[1] Glycerine is largely employed in suppositories.

4. *Glycerine soaps* do not enjoy the same repute as formerly, on account of the above-mentioned objectionable action on the skin if their use is long continued, and still more owing to the observation of Wanscheim (*loc. cit.*) that the addition of glycerine to antiseptic soaps lessens greatly their antiseptic value. "Glycerinum saponatum" has been largely used by Prof. Hebra in his clinic at Vienna, by reason of its rapid solubility in cold and warm water, and its property of dissolving a large number of substances and of holding other pulverulent insoluble substances in suspension.[2] It is a yellowish, inodorous, elastic mass, melting at the body temperature, and containing 80 to 92 per cent. glycerine, with 20 to 8 per cent. of a neutral cocoa-nut oil soda soap.

5. Hams and dried fish have been soaked in 20 per cent. glycerine with the idea of preservation.

Allyl Isothiocyanate, C_3H_5NCS, in the form of essential oil of mustard, or tincture of the seeds, has figured in a number of patents, and is undoubtedly capable of killing many organisms. This power, as with other condiments, may partly account for the instinctive selection for use with food, but it must be remembered that mustard itself undergoes change, especially when mixed with flour.

Boroglyceride has been discussed at p. 142. "Branalcane" is described as a 30·8 per cent. solution of Glyceryl Borate (Boroglyceride) in Glycerine, to which has been added 0·2 per cent. Resorcin, and the whole coloured with 0·002 per cent. of "Rubin": for throat affections, especially diphtheria. "Guaiamar" (Endemann) is guaiacol glyceryl ester.[3]

Oleic Acid, the fats, "Lanolin," etc., have no antiseptic power in themselves, but act as convenient vehicles for the

[1] *Chem. Centr.*, 1901, i., 408.
[2] *Pharm. Zeit.*, July 19, 1890; *Pharm. Journ.*, 3rd series, vol. xxi., p. 1,040.
[3] *Chem. Zeit.*, 1901, xxv., 1045.

application of antiseptics. Oleates of mercury, zinc, and other metals have, within late years, been found to possess a rapid absorption, to be more powerful than simple ointments, and to be less irritating.

Oils and ointments when applied to the skin may prevent infection by the exclusion of the germs, but Vicario observed that the fixed oils may contain germs, and that both they and any solutions to be mixed with them must be sterilized by heating to 100° C., or preferably to 120° C., in a digester, especially in the case of hypodermic injections of guaiacol, iodoform, and eucalyptol with olive oil for phthisis.[1] Dr. L. Baldas, in confirming the necessity of this precaution, found that B. coli, Staph. aureus and albus, and B. typhosus, retained their virulence in unheated oils for two months.[2]

Hydrocarbons of the paraffin series form the main part of petroleum, which has been already noticed (p. 200). Marco Polo, in the thirteenth century, said that petroleum from the Caspian Sea was used "to anoint camels that had the mange."[3]

Acetylene, C_2H_2, in solution or "pulverized" by projection with water or a disinfectant, is proposed by Choulet for the destruction of insects or for the treatment of diseases of plants.[4]

Vegetable Acids, like tartaric, citric, and malic, have the general power of inhibiting bacteria which prefer a neutral to an acid medium, but their effect is much less than that of mineral acids, and, as is well known, their solutions quickly become covered with mould in warm weather. Reinsch[5] states that ·028 per cent. of tartaric acid in water "began to diminish the bacteria, and 0·2 per cent. killed them." George Michel, in reviewing the possible methods for the purification and sterilization of the water supply of Marseilles, shows that citric acid may be used in the proportion of 4 parts per 10,000 for "paralyzing" cholera germs, and according to Dr. de Christmas, if used in double this strength it is absolutely fatal to these organisms.

Patent No. 1,297, 1893, proposes the use of tartaric acid for purifying water, and a filter has been devised to carry

[1] *American Druggist*, June 15, 1891.
[2] *Giorn. Real. Soc. Ital. d'Igiene*, February, 1901.
[3] *Encyclopædia Britannica*, vol. iii., p. 259.
[4] French patent 321,088 of 1902.
[5] *Centralbl. f. Bakteriol.*, 1891, vol. x., p. 415.

out this idea. Many patents use tartaric and malic acids to increase the solubility of boric acid and borax; it would seem as if they would rather diminish the efficiency by providing nutrient material, as exemplified by Pasteur's solution, which is used for growing organisms.

Oxalic Acid is an irritant and corrosive poison, and is said to be antiseptic. Its solutions certainly do not develop organisms; even the oxalates only allow their growth slowly. But in practice they are inapplicable. Succinic acid is slightly antiseptic.

CHAPTER XII.

PRACTICAL METHODS.

Towns: Limited Areas—Administration. Sewers and Drains: Ashpits and Dust-Holes. Houses: Walls and Wall Papers—Furniture and Wood Work—Sinks.—Sick Rooms: Isolation—Clothing—Excreta—Removal—Light and Air—Spray—After-Disinfection—Phenol—Sulphurous Acid—Chlorine—Liquid Disinfection by Spraying—Hot Solutions—Cisterns—Water-Closets—Earth-Closets—Middens—Cesspools—Infection by Flies—Automatic Distributors—Wood Paving—Urinals—"Urinal Cakes"—Stables—Pigstyes and Cowsheds—Cattle Markets and Fairs—Slaughter Houses—Dairies—Bakehouses—Pigeon and Fowl Houses—Rabbit Hutches—Cats and Dogs—Vehicles—Skins, Furs, Wool, and Hair—Rags. Disinfection of Air: Impurities—Sewer Gas—Vaporisers and Filters for Air—Water and its Purification. Preservation of Timber: Copper Sulphate—Creosote Oils.

In early times it was almost considered presumptuous to combat by natural methods the great plagues which frequently devastated the country, and only trifling efforts were made to control the ordinary infectious diseases that are always with us, such as diphtheria, typhoid, and other fevers. It is true that vinegar, camphor, and perfumes were used to protect the person from contagion, and that fumigation with aromatic woods was sometimes employed,

but these, as has already been shown, have only feeble powers in this direction. As the population increased, and overcrowding in towns grew general, the fatality from epidemics became excessive. Amulets of all kinds were almost the only remedies relied on. Even now, in the bubonic plague which was recently raging in Hong Kong, the faith of the people in charms, and their opposition to sanitary measures, was so intense that it was only under military force that the work of sanitation could be undertaken. Yet it is scarcely open to doubt that this plague (identical in its symptoms with the great plague of 1666 and other years, as shown recently by Kitasato, and still endemic in certain parts of the East), the Black Death, and the Sweating sickness, and, to a great extent, the cholera, are only kept out of Europe by modern applications of sanitary science. Harvey in the sixteenth century, and Bishop Berkeley in the eighteenth, seem to have been the first to advocate the combating of disease from the outside, and England was the first nation to organize a systematic campaign against infectious diseases. After the great outbreak of cholera in 1832, Parliament energetically resolved to frame regulations for public health; these emanated from the elected authority, and not, as in other countries, entirely from the police. The Public Health Act of 1848 constituted the Local Government Board as the executive sanitary power. Statistics were collected, and the country was divided into limited areas, which were distinguished as Urban and Rural Sanitary Districts, each with its Local Board of Health. The Urban districts included all towns except London, which has a special sanitary organization; Scotland and Ireland also have in part their own laws. The Urban authority centred in the Town Council. In rural districts the Board of Health and the Guardians are now merged in the Rural District Councils. Each body reports annually to the Local Government Board, which from time to time sends out recommendations in the form of a circular. Measures of disinfection are performed, superintended, or directed by the Sanitary Officer (Inspector of Nuisances) under the control of the Medical Officer of Health.

Sewers and Drains.—The old system of pouring large quantities of liquids, like carbolic acid, sulphate of iron, or permanganate down the drains with the object of disinfecting

the sewage, is now known to be useless, inasmuch as the re-agents are practically lost in the immense volume of water, and fail to reach a proportion sufficient to destroy the bacteria, although they may partially remove the smell. If an attempt is made to hermetically close the sewers, as was formerly supposed to be the best method for preventing a nuisance, the sewer gas, by backward pressure of rains or tides, passes through any form of trap into the houses, and, although sewer gas has been proved, owing to subsidence in the quiet atmosphere, to be almost free from germs,[1] yet there can be no doubt that it has a depressant effect, and lowers the vitality in such a way that men subjected to its influence are therein predisposed to infection. The fact that a few germs may be present must also be borne in mind. Consequently, the modern system is mainly confined to ventilation and flushing. Charcoal and disinfecting ventilators are elsewhere discussed (p. 15). Drs. Arthur and Illingworth proposed a new system of sewerage in which the side drains enter at the bottom of the main sewage.[2] They would soon be stopped up by backflow of solid matter.

In the large blocks of "workmen's dwellings," now so common in London and large towns, it is customary for the gratings of the house drains to be systematically sprinkled by agents with some popular disinfecting powder. M'Dougall's, Calvert's, or a pine-oil powder such as Sanitas, are commonly used. The author had occasion to examine this practice. Gratings were selected which evolved a distinct quantity of sulphuretted hydrogen, as proved by lead paper one foot over the drain being discoloured. After sprinkling with either of the powders, the fœtid odour, both of sulphuretted hydrogen and of sewage, seemed to be actually removed, and not merely disguised, and the lead paper was no longer affected. The effect, however, only lasted from an hour to an hour and a-half; after this the smell was as strong as ever, and the lead paper was again discoloured. The odour was most powerful in the mornings, or on the approach of a storm. In one instance several cases of diphtheria had occurred, and a general cachexia

[1] *Journ. Soc. of Chem. Ind.*, 1888, p. 911; also J. Parry Lawes' *Report to the London County Council*. 1893.

[2] *Sanitary Record*, 1894.

was noticed in the inhabitants, in all probability attributable to this sewer gas. Yet in many of these places, when a complaint is made, a roadman is sent with disinfecting powder, and the nuisance is temporarily abated, instead of the defect in the drain being seen to. So that this method of disinfection is not only useless, but is positively to be condemned, as it leads to a false idea of safety, and hinders genuine sanitation. Sanitary inspectors should always visit these places in the early mornings before the roadmen have sprinkled the disinfecting powder.

Chloride of lime retains its power for a very much longer time, on account of the gradual evolution of chlorine by the action of the carbonic acid of the atmosphere. But even this is inefficient. Its smell to most people is exceedingly unpleasant, and the gratings and pipes are quickly corroded; hence its general abandonment for this purpose. A daily flushing of the drains, except in rainy weather, with water seems to be one of the best methods for preventing a nuisance. It has been proposed in several patents to suck the smoke from house and other fires into the sewers, not only to get rid of the soot, but with an idea of disinfection, but as it is necessary for workmen to enter the sewers, it is not easy to see how the smoke could be temporarily suspended.

As to Ashpits and Dust-holes, if they are frequently emptied and care is taken to burn putrescent matter and not to throw it into these receptacles, there is not much danger. Portable ash-bins of galvanized iron are much used in London. To sprinkle disinfectants over the refuse is futile, though they may be used with some advantage in the empty dust-bin after removal, and over the contents of the dust-carts in their passage through the streets. Stingl and Neuman have a patent[1] for an improved refuse collecting van, with double dust closure and an automatic disinfecting device. A portable petroleum destructor for house refuse has also been advocated for this purpose. Most urban authorities have now a difficulty of disposing of their refuse, and many destructors and cremators are in use. A simple domestic apparatus, invented by Mr. J. B. Petter, has been most favourably reported on by Dr. Garland, M.O.H. for

[1] No. 47, Jan., 1894.

Yeovil. It is easily fitted up in conjunction with the kitchen range, and provides a ready means of destroying, day by day, all refuse such as potato peelings, cabbage leaves, fish bones, etc., thus doing away with the accumulation in the dust-bin. The destructor is absolutely inoffensive when in use, the escape of fumes being adequately guarded against. Further information on Dust Destruction will be found in Rideal's "Sewage," 1901, pp. 166-174.

Houses.—Fresh air, light, and frequent cleansing are the essentials to be aimed at in thickly-populated districts. In washing floors a strong carbolic soap, or better, a cresylic preparation, is very useful. Curtains and bedding must be occasionally brushed and shaken in the open air. When sweeping floors and carpets, tea-leaves, or damp sawdust should be used to prevent the diffusion of germs in the dust. Oil paint, or a well-varnished paper, are preferable for walls, as they can be easily washed. A very important point, especially in connection with hospitals, is that walls should consist of impervious material not affording a lodging place for the growth of disease bacteria. Several exhibits with this object were shown at the Building Trades Exhibition, 1903.[1] Flock papers have become obsolete, from their forming such a favourable nidus for the growth of organisms. Ordinary papers are sometimes cleaned with bread crumb, to avoid dust, but the removal of bacteria is incomplete.[2]

Hygienic Wall-papers prepared with various disinfectants incorporated in the pulp have been suggested. Mercuric chloride has even been proposed to be introduced, but its use should not be permitted on account of the danger of its being evolved in the dust. Resorcinol, 1 in 2,000, is patented by Sinclair and Brown for this purpose.[3] It has been proposed to incorporate salicylic acid with the plaster coating of walls; it is non-volatile and inodorous, but it is very doubtful if it would be efficacious. It always communicates a pinkish colour, owing to the presence of iron salts. Kosinsky, of Warsaw, invented a portable apparatus for heating air to any required temperature and forcing it at the rate of about 1000 cub. ft. a minute through radiating tubes against walls and other surfaces for drying and disinfection.

[1] *Sanitary Record*, 1903, p. 583.
[2] See an article on Disinfection of Walls, *Ibid*, 1899, p. 298.
[3] Patent No. 12,217, 1886.

It is also intended for large disinfecting chambers, in which the rapidity with which the air passes combines with the high temperature (stated in the report to be 660° F., but this is obviously an error) in bringing about the desired result. It is also suitable for warming buildings, and for removing vapour and moisture from crowded rooms—*e.g.*, in a theatre, after the exit of the audience, to prevent the condensation and settlement of injurious moisture and dust. An official commission at Warsaw proved that a private house, the building of which was commenced in May, 1882, with the capacity in ground floor and first storey of 7,000 cubic feet, was completely dried in fourteen days, and severe sanitary inspection proved the building to be completely sterilized.

Furniture and Woodwork can be washed and scrubbed, or, in special cases, should be washed with 1 in 1,000 mercuric chloride (in a few instances this may cause discoloration), or with 1 per cent. formaldehyde (2½ per cent. formalin), taking care of the hands. Upholstered furniture, when infected, requires very careful and thorough treatment; it should be avoided in bedrooms. Beeswax and turpentine are better than the common furniture polishes, as the surface is to some extent disinfected and rendered non-absorbent. All cracks and crevices should be carefully filled up with putty to prevent the lodgment of vermin or germs.

Sinks, if made of stoneware, can easily be cleaned. Here Condy's fluid (permanganate) is serviceable, but strong soda is ordinarily better. For toilet utensils sodium hypochlorite (chlorinated soda) in 5 per cent. solution should be occasionally used, also for milk cans and pails. In the case of metal baths it should not be used too strong as it removes paint. Bedsteads, in addition to scrubbing with soap and water, can be afterwards washed with chloride of lime and water, 10 per cent., and left in the air till the odour has almost disappeared. Paraffin oil is sometimes used, but its odour is very persistent. Polished floors are to be recommended in preference to porous floors and carpets.

Sick rooms cannot be disinfected in presence of human beings. All placing of saucers with chloride of lime, permanganate, etc., under the bed, or about the room, all hanging up of sheets dipped in disinfectants, are simply illusory. Similarly fumigation by medicated lamps or candles, burning pastilles, or brown paper, are useless.

Sufficient of the disinfectant to kill the micro-organisms of the air would make the air unfit to breathe. The following precautions, however, will be of service.

1. *Isolation.*—If possible, the other inmates of the house should live on a different floor. Where this, on account of poverty or other cause, is unattainable, contact should be carefully avoided.

2. *Clothing.*—The attendants should wear cotton and linen, not woollen, garments. This is now compulsory in hospitals and most institutions. The greatest personal cleanliness should of course be observed. The following is a way of removing soiled clothing from the room:—At the bottom of a large air-tight tin trunk, such as is used for travelling to India, is placed a piece of felt or blanket, or three or four thicknesses of flannel. This is sprinkled with crystals of carbolic acid, and covered with a linen cloth. The crystals will soon deliquesce, and soak into the stuff. The lid should never be left open. The soiled clothing is put in, and when full it is left for an hour for the phenol vapour to penetrate, and then carried out into a yard, where it is filled with boiling water containing soda, and washed as soon as possible. The washing must never be done, nor the clothes hung out to dry, on the same day as the ordinary house washing, nor should they be ironed or starched in the same room or with the same utensils. This dry method of removal of clothing is probably better than the usual one of plunging into a disinfectant solution (phenol or mercuric chloride), as it is easier, and the weight of the water and constant carriage are avoided.

3. *Excreta,* vomit and sputa, according to earlier directions, should be received into about a pint of mercuric chloride solution, 1 per mille, with 10 per mille of common salt and 1 per mille of hydrochloric acid, coloured with indigo to avoid mistakes, a large quantity of such a solution being kept ready. (See p. 184). Dr. Fischer recommended aniline water for disinfecting tuberculous sputa (p. 240). "Five per cent. phenol did the same in twenty-five hours; mercuric chloride, 1 in 500, failed. Dry heat of 100° C. sometimes failed, though it acted for sixty minutes. Boiling ten minutes, or steam for fifteen minutes, succeeded."[1]

[1] *Mittheil. Kais. Gesundh.*, 1884.

Disinfected excreta must not be thrown away before the agent has had time to penetrate. If disease begins in houses where the sick person cannot be properly accommodated and tended, medical advice should be taken as to the propriety of removing the patient to an isolation hospital. "Where dangerous conditions of residence cannot be properly remedied, the inmates, while unattacked by disease, should remove to some safer lodging."[1]

As has been previously indicated, a chemical disinfectant will frequently combine almost instantly with organic or other matters present, thereby becoming partially or entirely inert before it has time to attack the bacteria. Hence the difficulty of chemical sterilization of sewage. It is true that it may tend to starve or inhibit the organisms by removing their food, but the amount of food they require is so small and so widely diffused that such a consummation is hardly practicable. I give further (p. 351) an instance of the rapid destruction and inefficiency of permanganate. Phenol and a number of metallic solutions are equally liable to loss from their precipitating albuminous substances. These observations apply with still greater force to solid and liquid excreta.

Hill and Abram,[2] from experiments with fæces, concluded that either carbolic acid 1 in 20, crude carbolic 1 in 40, "formol" (40 per cent. formaldehyde) 1 in 40 [?], chinosol 1 in 600, creolin 1 in 40, mercuric chloride 1 in 500, "may be regarded as absolutely certain when thoroughly mixed with the stool and allowed to stand for half an hour." Their criticism of this group of agents is briefly as follows:—

Mercuric chloride is a scheduled poison, acts on metal work; coagulates albumen, so that organisms in the centre of the coagulum may escape attack; and gives a red reaction with stercobilin, which may mask the presence of blood in a typhoid stool. Phenol does not mix well with fæces, stains linen, and is poisonous. "Formol and creolin are good, but rather costly." They give the preference to chinosol as an excellent deodorant, mixing well with the fæces. Their results as to comparative quantities required are not, however, in accord with my own observations.

[1] *Circular of Med. Off. Local Gov. Board.*

[2] *Brit. Med. Journ.*, April, 1898.

In Houston's experiments[1] the total bulk of fæces, urine and paper was mixed with the disinfectant and tested after 1 hour. He concluded that 1 in 500 of mercuric chloride, 1 in 100 of izal, 1 in 20 of copper sulphate, or of carbolic acid, were all efficient, but 1 in 75 chinosol was not successful. "Formalin, lysol, creosol, and creolin were also experimented with and found to be of value." Pouring 4 parts of boiling water, containing 1 per cent. of crystallized potassium permanganate, over 1 part of the excreta, so as to raise the temperature in 5 minutes to 63° C., killed B. coli and effected surface sterilization without nuisance. The use of this proportion of boiling water was recommended many years ago by Dr. Sternberg in America, and it is stated to have been successfully carried out in South Africa, but the odour evolved has been a difficulty.

Prof. B. Körber, in the Dorpat cholera epidemic of 1893, used quicklime for disinfecting the dejections (see also p. 149). It was distributed by the authority to the inhabitants, and as milk of lime was added to the water. Cesspits were in the first instance charged with 100 kilos. of lime, and if after twenty-four hours the contents were not alkaline, more lime was added.[2]

Various metallic and other solutions have at times been employed for disinfecting discharges, but the majority simply effect deodorization. Zinc Salts were at one time in much favour. See p. 152.

Where infected fæcal matter has once gained entrance to a system of water supply it is difficult to secure dislodgment of the dangerous organisms, as they may remain entangled in the zoogloea masses of micrococci which collect at small obstructions, or among the filaments of crenothrix, cladothrix or algæ. It is obviously impracticable to use a poisonous disinfectant. After the typhoid epidemic at Maidstone in 1897, the reservoirs and water pipes impugned were filled with a solution of chloride of lime, under the direction of Dr. Woodhead. No corrosion of the iron pipes was noticed. Subsequent copious flushing is necessary, as the water for some time, besides having its hardness increased, would acquire a chlorinous odour and taste, and would be liable to act on lead. The presence of

[1] *Practitioner*, Sept., 1902, pp. 309, 332.
[2] *Zeits. f. Hygiene*, 1895, p. 161.

the reagent at the outlets should be tested for by iodide of potassium and starch (p. 92) and by nitrate of silver. At Sprottau, Silesian Prussia, the following method of disinfection was resorted to as a last means during the typhoid epidemic in 1894:—The whole pipe system was cleaned by means of steam forced through it by a portable boiler. A boiling solution of soda was then pumped through the pipes. For this purpose six tons of soda were thrown into the water reservoir and brought to boiling point by means of steam.

In comparing liquid sterilization of typhoid excreta with destruction by heat it must be borne in mind that the utensils cannot be subject to the process of heat destruction, and their contents being largely of a liquid character have to be absorbed in sawdust or some porous material and thence emptied into a destructor, leaving the utensils nearly dry and still to be cleaned and disinfected. These manipulations take time and materially increase both the danger to the staff which performs them and the area of surface which threatens general infection.

The disposal of excreta was attacked in several ways during the South African campaign. The method which has commended itself most by its results is that of Major Cummins, and an improved form of his apparatus has been supplied for use in Netley Hospital (Fig. 21).

It consists essentially of a boiling pan F, divided into two compartments, one for the contents and the other for the utensils. The pans are filled from any water supply or by buckets; about half an ounce to the gallon of crude carbolic is added and appears to prevent any offensive smell, even from the carbolic itself, from being perceived during the operation, this result being probably in some measure due to the arrangement by which the furnace gases sweep the volatile matters up the chimney. The vessels are automatically emptied by a syphon C, which is started by throwing over a valve by the lever D. Gas, coal, wood or steam is used at G for heating; and for field purposes the vessels are arranged to nest and the fire lit in the usual way.

With special reference to cholera discharges, Blachstein[1] has recently drawn attention to a singular property of

[1] *British Med. Journ.*, 1, 97, 28, from *Pharm. Journ.*

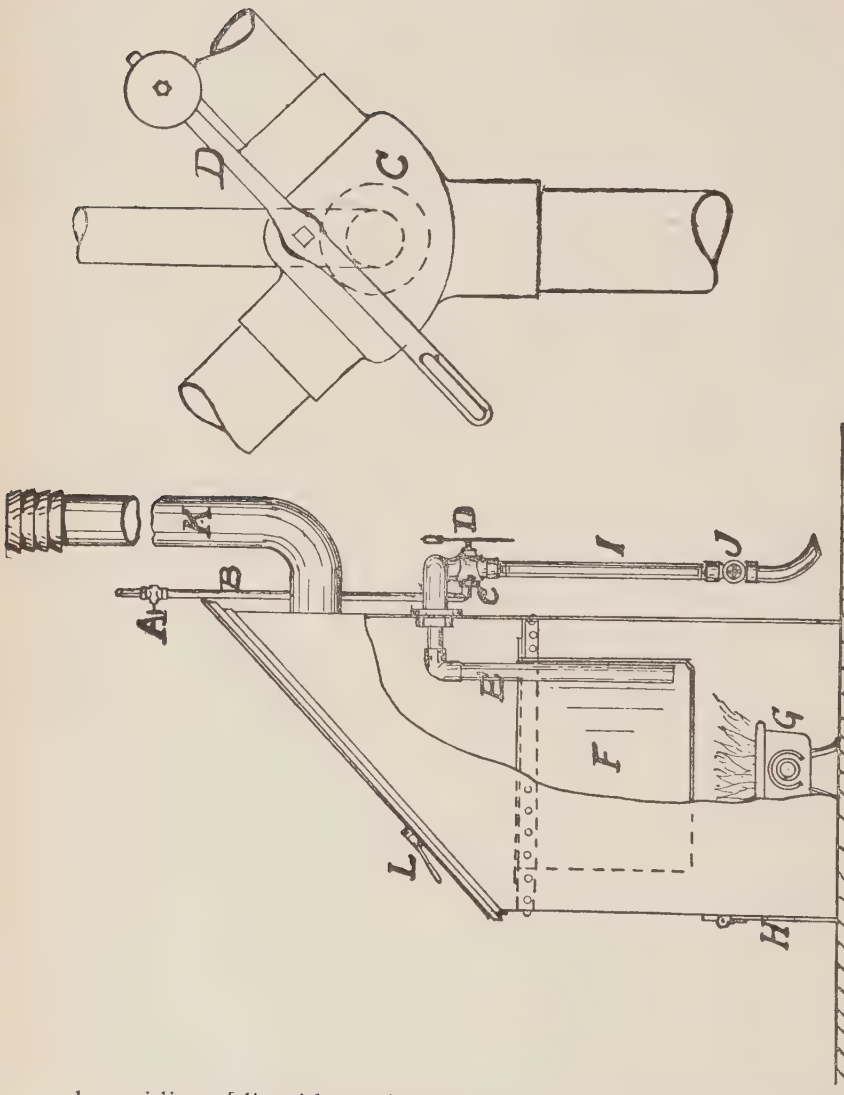


Fig. 21.—Apparatus for Sterilization of Dejecta.

chrysoidine [diamido-azobenzene, $C_6H_5.N:N.C_6H_3(NH_2)_2$, orange coloured crystals]. He states that it precipitates Spirillum choleræ from suspension, that the same peculiarity belongs to the serum of those immune from cholera, and that no other body besides chrysoidine is known to possess this property. Animals inoculated with cholera bouillon containing chrysoidine continued to live, while the same

bouillon without the dye caused infection. Experiments are necessary as to its use in this direction and the quantity required.

Mucous discharges, like sputa, etc., are exceedingly difficult to disinfect on account of their consistency and clinging properties, yet they are specially dangerous, as entangling large numbers of bacteria. Alkalies dissolve mucin, and it is precipitated by acids. Goriansky,[1] however, finds that pyroligneous acid acts energetically on the sputa of tuberculosis (the bacillus of which is unusually resistant) if mixed and left in contact for five or six hours. "Vessels used to collect the expectoration of tuberculous patients should contain a fair quantity of the acid."

Disinfection by heat would seem to be the ideal method of dealing with infected discharges, but the odours evolved create a practical difficulty. Assured sterilization must include the destruction of the *spores* of the most resistant bacteria, and can only be attained, as proved by Esmarch and other observers, by the *whole mass* being exposed in presence of water to a temperature of 130° C. for ten to thirty minutes. This would involve the replacement of the ordinary chamber utensils by special metallic vessels with steam-tight covers capable of withstanding an internal pressure, due to the aqueous vapour, of about 3 atmospheres. The dejecta could be received directly into these vessels, covered, and immersed in a vessel containing a solution of chloride of calcium (about half-saturated) heated to 130° C. for half to three-quarters of an hour. On cooling, the vessels could be with perfect security washed out into the drains and used again. With regard to the heating of the chloride of calcium bath, it must be remembered that the temperature of 130° must not be exceeded, or the sealed receptacle may be risked. It is difficult to regulate the temperature of so large a vessel on an open fire; with a gas stove it would be easy. The apparatus and attention required are not unattainable even domestically, and the immediate dealing with the germs would seem to be the soundest method of preventing a spread of the disease.

4. *Light* and air should be freely admitted. Vallin strongly recommends the use of water spray in the room, as

[1] *Journ. de Pharm.* [6], ii., 67.

he says that the water entangles the bacteria and dust, and the dissolved oxygen in the water destroys them. He also approves the use in the water of a small quantity of resol[1] (dimethyl-resorcin), a body proposed by M. Pabst, as agreeable and non-corrosive. A 1 per cent. solution of peroxide of hydrogen, or a preparation like Sanitas might also be employed for the same purpose. The sick person should be protected by a screen from this process, from draughts, and from too much light.[2] It is well known what benefit is derived in some lung diseases from the common bronchitis kettle. Dr. W. Ferguson has suggested its use as a fumigator in pneumonia and diphtheria by the following simple modification:—"Take an ordinary bronchitis kettle, remove the first joint, and replace it by a common tin funnel loosely filled with tow. Pour on the tow 1 drachm of pure phenol, and at intervals more. The steam carries off the phenol."[3] But whatever utility these practices may have *medicinally*, we must again emphasize that they cannot be considered as *disinfection*. Curtains, hangings, carpets, and all unnecessary furniture should be removed.

After-disinfection.—Phenol, chlorine, and sulphurous acid have each had their advocates.

(*a*) *Phenol.*—Pouring strong carbolic acid on a hot shovel is dangerous to the operator. Calvert manufactures a perforated iron cylinder delivering a mixture of 2 parts phenol and 1 part water on to a red-hot iron heater; the whole is compact and can be carried by a hook. There is also Savory and Moore's vaporizer, in which phenol falls on a hot plate, and many others. But phenol vapour is not reliable as a disinfectant (*Miquel* and others[4]), and the smell remains persistent. The following is the substance of directions given at various times by the Local Government Board and other authorities for disinfection by chlorine or sulphurous acid. These agents, however, have now been largely displaced by formaldehyde (see p. 310).

(*b*) *Sulphurous Acid.*—After the removal of such articles as are best disinfected by heat, and the closure of windows and crevices, the gas in ample quantity should be evolved,

[1] Not the commercial "resole" or "resol" of pp. 220, 235.

[2] *Désinfectants*, p. 407. [3] *Lancet*, 1880, vol. xi., p. 757.

[4] See also *Pharm. Journ.*, [3], ii., 545.

the doors being closed for six hours or more. The amount of gas required for the disinfection of a moderately-sized room can be obtained by burning 1½ lbs. of roll brimstone in a pipkin over a small fire placed in the middle of a room, with an old tray or the like to protect the flooring. These processes should be effected by skilled persons acting under the directions of the Medical Officer of Health. All wall-paper should be stripped from the walls and burned, and the same room ought to have its ceilings and walls thoroughly washed and lime-whited.[1] Boake's liquid sulphurous acid, bottles or tins, are much more convenient (see p. 128).

(*c*) *Chlorine.*—3 lbs. of good chloride of lime and 3 lbs. commercial hydrochloric acid should be used for every 1,000 cubic feet. This quantity is divided into several parts and placed in deep stoneware vessels as high as possible (since chlorine gas is heavier than air), and the acid allowed to drop in gradually by a funnel with narrow tube. The room should then be closed for twenty-four hours. But the operation presents many difficulties in practice, requires the removal of metals or the protection of fixtures with vaseline, sometimes involves much damage, and the subsequent opening of the room is very dangerous even when breathing through a towel soaked in ½ to 1 per cent. ammonia solution. Finally it is not always successful (pp. 82, 83), and has been virtually abandoned.

In the above fumigation with chlorine there is an important omission. Inasmuch as the dry gas will not disinfect (p. 79), it is necessary to generate steam by a boiler or large kettle over a good fire for some time before commencing, so as to make the whole room and the air thoroughly damp, but not too wet. As to SO_2 see p. 134.

(*d*) *Non-volatile disinfectants* can be applied by mechanical means. Thus bleaching powder can be used as a wash, and the walls, floor, and ceiling coated by means of a brush. Mercuric chloride solution and formalin, or, in fact, any liquid disinfectant can be sprayed into the room. Many forms of sprayers have been devised. The *Equifex* is so constructed that the fineness of division and the force and velocity of projection can be varied at will; for this purpose the channel for the disinfectant is arranged to reduce the

[1] *Circular of Med. Off. of Health, Local Government Board.*

velocity of the liquid at the point of delivery to a rate which is very small, and capable of being exactly controlled by turning a cock. For a given velocity of air, regulated by another cock, the force of projection will therefore be determined by the velocity of the air, which is controlled by the pressure to which the pump is worked, and the degree to which the air cock is open. The importance of a fine division of liquid depends on the fact that it enables the work to be done with the minimum useful amount of disinfectant, saving the expense and inconvenience of waste liquid. The parts containing the disinfectant are lined with ebonite, so that these sprayers may be used with any liquid disinfectant without any risk. The cost will vary slightly with the disinfectant used. Taking perchloride of mercury 1 in 1,000 solution, it is found that an ounce of salt disinfects more than 3,000 square feet of surface. The time occupied in the operation is about an hour per 1,300 square feet.

B. Kuhn's "Nobro" apparatus is a double-action suction and force pump in a 5-gallon portable reservoir, with a fine and a coarse spray, and with fittings capable of bearing a considerable temperature without injury. It is worked by the weight of the operator, leaving both hands at liberty to direct the jet, which will carry 40 or 50 ft.

The *Chloros Distributor* is specially for outside work. It has an injector jet like a Bunsen pump by which the water from the street main draws in and mixes with a quantity of the disinfectant, regulated by a screw needle valve.

Dr. Leslie Mackenzie pointed out the advantage of spraying out hospital wards at intervals, and found that in a scarlet fever ward various minor affections disappeared after formalin spray had been used while the ward was temporarily emptied for a few days. The "Mackenzie Spray," sold by the Thresh Company, is a pump with air-chamber capable of maintaining a steady jet for 10 minutes.[1] The "Invicta" Sprayer, made by Lumley, of America Square, London, is a portable tank into which air is driven until a pressure of 15 lbs. is recorded on the pressure gauge, then the disinfecting liquid is forced in with the same pump until 45 lbs. pressure is reached. The quantity of liquid is about 1½

[1] *Brit. Med. Journ.*, 1901, p. 898.

gallons; the spray will last about 20 minutes, and is controlled by a stopcock. The exit is by a tube with ball valve, coming from the lower part. It has been improved and adopted by Dr. Robertson, M.O.H. for Leith,[1] and he reports that it is very successful.

The State Board of Maine in 1900 issued a special circular of directions for disinfection of rooms, furniture, etc., used by consumptives, in view of the difficulty of killing B. tuberculosis. Details are given of the employment of steam or boiling for fabrics, and of formaldehyde gas and spray for rooms and upholstered furniture. 50 c.c. of formalin poured upon a cloth in the lower part of a disinfecting chamber of 1,089 cub. in. capacity, disinfected books that were standing on end in 24 hours, but not those lying flat.

Letters. At some asylums all letters are disinfected with dry steam before sending out. Rosenau at Havana treated the mails by clipping off a corner of the envelopes and dropping in a little formalin from a fine jet, then keeping them over night in a sack or tight box, sprinkled with the disinfectant.

Clothes, bedding, mattresses must be removed at once in a closed van to a disinfecting station, to be treated with superheated steam. Dry hot air is now only used in special cases (books, leather, and some other materials) and apparatus solely for this purpose is not often made (see p. 32). Occasionally, however, a baker's oven may serve, if not for the destruction of the spores of splenic fever, for killing the non-sporiferous bacteria of cholera, typhus, and diphtheria, and especially for animal vermin (*Klein*). The bodies of persons who have died of infectious diseases should be at once wrapped in a cloth soaked in 1 per cent. solution of mercuric chloride prior to burial or cremation.[2] Adolf and Heider find that hot solutions of disinfectants are much more active than cold.[3] In Belgium infected clothes are boiled in a solution of zinc chloride, or with a mixture of 240 grammes zinc sulphate and 120 grammes salt dissolved in a pail of water. Commercial zinc salts cannot be used, as the presence of iron salts causes them to produce stains on linen.

[1] *Public Health*, May, 1903.

[2] See also *Medical World*, Dec. 17th, 1898.

[3] *Arch. f. Hygiene*, vol. xv., p. 55.

At Aberdeen the Medical Officer of Health reports[1] that house, bedding and clothing are dealt with, and other details are treated, with exceptional care. The infected rooms are fumigated with sulphur, washed with water containing formalin—a sufficient quantity of which is supplied gratuitously for each case by the sanitary department—and the clothing and bedding are removed for steam disinfection at the disinfecting station.

In India, according to the report of the Plague Commission the disinfection of houses that had contained cases has been universally carried out. The disease sometimes recurred in the same building, in one instance 34 days afterwards, but may have been due to a fresh infection. Mercuric chloride was generally used, and in Poona was pronounced efficient if operated by British soldiers, while in Baroda there was frequent recurrence in houses thus disinfected under the supervision of the health officer himself. Mr. Hankin showed that the cow-dung which is so large an ingredient of the floors of native houses contained much alkali and other substances which precipitate the mercury, and that the remedy was to be found in strongly acidifying the solution. Peroxide of hydrogen was also said to have been successful. The digging out and burning of the floors was dangerous to the workmen. Unroofing and exposure to sun and air was of service in the dry districts of Sind and the Punjab, but was not always practicable. All operations involving disturbance should have been accompanied by liberal spraying.

Hospitals obviously need special precautions, and are generally provided with their own steam disinfecting plant, and in many cases with cremators for the destruction of infectious stools, bandages and valueless articles. The polished wood floors are cleansed regularly with 1 in 20 carbolic acid or an equivalent of another disinfectant, and the walls, fittings, and utensils[2] are attended to in the ways we have indicated.

Cisterns for drinking water must never be connected with the water-closet tanks. They must be occasionally scrubbed out, every three or six months, according to the

[1] *Public Health*, July, 1903, p. 584.

[2] See an article by Dr. Louis Parkes, *Ibid*, June, 1903, p. 540.

quality of the water: if made of lead, care should be taken not to expose the metallic surface, or lead may get into the water. If any foul deposit, or confervæ, have collected on the sides, the cistern should be brushed over repeatedly with a solution containing 5 per cent. permanganate crystals and 5 per cent. sulphuric acid. Householders can have a quart of this solution made up at a chemist's (water 1 quart, potassium permanganate crystals 2 ounces, sulphuric acid 2 fluid ounces; cost about 6d.). The solution should be used till the pink colour of the permanganate remains for an hour, afterwards well flushing till all colour has been removed. A slight brown coating of peroxide of manganese on the sides will be advantageous, by serving as an oxidiser, and preventing further growth. Several inventions have been introduced for allowing a small quantity of permanganate solution to be constantly admixed with water, but any admixture of a chemical, except a minute quantity of slaked lime, properly used as in Clark's process (p. 21) would be injurious. Apparatus of this kind, such as Wade's siphon arrangement, are, however, of service in small cisterns used for closets and urinals. It has been pointed out in the *Lancet*, that water lying stagnant in cisterns while families are away for holidays may be a source of danger. When a rain supply is used for drinking in cottages in remote parts, care must be taken that the water-butts are kept very clean. Iron tanks are better than wooden barrels.

Water-Closets should be of modern patterns, admitting of washing, flushing, and proper cleaning and with walls of cemented tiles or lime-washed. The above solution of acid permanganate should be used occasionally to cleanse the pans. Chloride of lime should not be used, as it corrodes the metal fittings, and has often caused serious mischief by eating holes in lead or iron siphon traps. Mercuric chloride also corrodes lead pipes. The flush of water at each using should be preferably 3 gallons. A valve closet, though rather expensive, seems to be the best form for indoor use.

Earth-Closets were introduced by Moule, in 1863, with the object of saving the manure, as well as for immediate disinfection of the fæces. Earth is popularly believed to be a universal disinfectant, yet Koch showed that it abounds in organisms, some of which are pathogenic. For closets it requires to be previously dried, or preferably baked in an

oven: it then becomes very absorbent, and instantly removes all odour when only a light covering is spread over the excrement. But its effective use is ruined by the discharge of urine at the same time; if this could be kept separate the process would be of value for agriculture. Unfortunately the manure rapidly loses value on account of the evolution of ammonia. As regards sanitary efficiency the quality of the material is more important than its quantity. Sand and gravel are inert, chalk feeble, and dry clay good, whilst garden soil, loam and peat give the best results;[1] 2 lbs. of dried earth at least are required for each evacuation. At Wimbledon Camp in 1869, when 140 tons of dry earth were used in a fortnight for 30 tons of excreta the deodorisation was complete.[2] Green and white moulds destroy the fæcal matter, and in 5 or 6 weeks it is indistinguishable from ordinary earth, so that it can be safely dug or ploughed into gardens or land, and has been found beneficial to soils, although it contains only about a tenth per cent. of nitrogen and half per cent. of phosphoric acid. Pathogenic organisms are not killed by the process, but do not seem to escape, as there is no record of epidemics having been caused. For places without a copious water supply, this system is better than pails, and much superior to privies. Dr. Poore advocates an earth system for rural sanitation.[3]

The Goux-Thulasne Method is a combination of the earth and the pail systems. In an iron tub with handles a slightly conical core is held, and the intervening space packed with dry earth or a pulverulent disinfectant. When the core is withdrawn, a cavity of the same shape is left. Tubs thus prepared are carried round on drays and left at the houses. At the end of a few days they are collected, shaken so as to cover the excreta with powder, and closed with an air-tight iron lid before removal. They must be kept from the rain. A funnel can be arranged in the front part of the closet opening to collect the urine separately, so that the earth or powder is not wetted.

A Self-acting Earth-Closet has an upright box at the back containing the dry earth, etc. By a rack-work and

[1] Buchanan and Radcliffe, *Report* of 1869.

[2] *Lancet*, July 24th, 1869.

[3] "The Earth in Relation to Contagia," *Longmans*, 1902.

lever, worked by a handle in the ordinary water-closet fashion, a valve at the bottom of the box is opened, allowing a certain quantity of earth to fall on the fæces at each evacuation. The receptacle is a large ordinary zinc pail. Or the arrangement may be made automatic by a hinged seat. In Norris's patent,[1] the solids are separated by a grating and mixed with earth, the liquid portions pass down the drain, which is ventilated by a current of fresh air and connected with an ordinary ventilating shaft.

Pail System.—In villages and some towns on the Continent the excreta are discharged into pails, which are collected at night-time, and the contents, with or without a perfunctory disinfection, emptied into ditches or pits, which when full are covered up with earth. From this primitive and dangerous practice, the material has come to be called night-soil. Even this is, however, preferable to the old system still surviving in English country districts, and even improperly permitted in some towns (but not in London)—namely, that of

Privies, wherein the fæces and urine fall into a brick pit, which is cleared out at intervals. The soil is infiltrated, and the infected drainage has often penetrated for years into wells used for drinking water, and has been the cause of numerous epidemics.[2] At Rochdale the pail system has been much improved. The excreta and ashes are collected separately and the former converted into dry manure, whilst the latter yields fuel for a refuse destructor and steam production.[3]

Cesspools can only be dealt with by pumping out the contents and distributing them over land. They cannot, obviously, be disinfected.

S. von Gerloczy,[4] in an investigation of disinfectants at the Pesth Hygienic Institute, found that a practical disinfection of night-soil on the large scale was all but impossible. Even $2\frac{1}{2}$ per cent. of mercuric chloride was insufficient to render it germ-free (costing £9 10s. per cubic yard). Complete disinfection resulted when 4 per cent. of cupric sulphate was used, but the cost of it would also be prohibitive. In

[1] No. 20,726, 1891.
[2] See Dr. Porter's Johannesberg report, *San. Record*, Nov. 13th, 1902.
[3] *Journ. Soc. Chem. Ind.*, 1895, p. 340.
[4] *Deutsche Vierteljahresb. öff. Gesund.*, 1889, p. 433.

sewage matter 1 per mille of copper sulphate destroyed all germs and rendered it clear and inodorous

According to the model bye-laws of the Local Government Board, the occupier of any premises shall cleanse every earth-closet on his premises, or fixed receptacle, at least once every three months (this interval is found sufficient for sanitary purposes, as under the proper use of dry earth the stools and even the paper become disintegrated and disappear without fœtor in the compost—*Newsholme*); those with a movable receptacle at least once a week (so that the pails may be manageable during scavenging); privies and ash-pits once a week; and cesspools every three months; and that between 6 and 8.30 a.m. in summer, and 7 and 9.30 a.m. in winter.

One of the great dangers of leaving fæcal matter exposed is the visits of flies. The bacteria of tubercle, splenic fever, typhoid, and European cholera pass through the digestive organs of flies, and reappear in their excrements with unabated virulence.[1] They are also carried adhering to the feet and legs of these and other insects.[2] A covering of chloride of lime or of a coal-tar powder has the merit of keeping them away. There is a vast number of patents having for their object the introduction of disinfectants into the pan or into the flush water of closets. Cakes of naphthalene, tablets of plaster of Paris mixed with manganate or permanganate, zinc sulphate, thymol, etc., are of little value. Automatic distributors designed to keep the drains flushed with liquid disinfectants give better results. To continually supply sufficient of a disinfectant to a closet would, however, be very expensive.

Sanitary officers must proceed with caution in disinfecting private dwellings, and must give proper notice, as it has been proved that an action for damages can be maintained unless the disinfection is legally carried out.[3]

Streets are watered and cleansed by the Borough and Urban Sanitary Councils. It is important to remove refuse and animal excreta immediately, as the surface, even when paved, is porous, and the soil is a favourable nidus for the growth of micro-organisms, which escape in the dust. Mixing

[1] *Centralblatt f. Bacteriol.*, 1888, vol. iv., p. 486.
[2] Report on enteric fever in S. Africa, 1903.
[3] For particulars of such a case at Filey see *Lancet*, April 10, 1880.

disinfectants with the water in the carts is of doubtful utility, as the chemical must be much diluted, and the area to be covered is often large. Such a procedure may perhaps offer a certain restraining influence on the microbes, but, as ordinarily done, it is often a waste of public money. It is of course impossible to disinfect the open air.

I may quote an example from my own experience. In July, 1900, I watered two plots of street asphalt under ordinary day conditions with (*a*) ordinary water, (*b*) a 1 in 5,000 solution of permanganate (the strength then locally used). The liquids running off were collected and bacterially examined. The permanganated sample was almost free from odour, and on keeping for three days smelt much less foul than the other. The cultivation experiments showed the following results:—

		Colonies per c.c.
Gelatine plates at 22° C.	(*a*)	1,930,000
	(*b*)	85,000
Agar plates, at 37·5° C.	(*a*)	0·001 c.c. gave numerous colonies, and plate was too crowded in 20 hours for counting.
	(*b*)	0·01 c.c. gave a similar result.
Carbolised gelatine plates at 22° C.	(*a*)	122,200
	(*b*)	4,830

Although the permanganate has exercised considerable influence, destroying about 96 per cent. of the bacteria, the result cannot be considered sterilization, and it will be noticed that its effects upon those growing at blood heat and on carbolized gelatine, which include those of the "coli" group, was similar to that on those growing on the ordinary gelatine plate. I did not specially test in these experiments as to the survival of spores of *B. enteritidis sporogenes*, but from previous work with this organism I believe it to be extremely resistant to permanganate.

The main work must be done in houses, and in narrow streets and courts. It would be better if these latter were paved with asphalt or some similar non-porous material. An asphalt pavement made properly is aseptic, and to a certain extent antiseptic. For disinfecting courts and yards distributors such as we have just described are required.

The danger arising from unpaved back yards has been repeatedly shown,[1] and section 23 (1) of the Pub. Health

[1] *Public Health*, Oct., 1902, p. 41.

Acts Amendm. Act, 1890, confers powers to enforce their impervious paving. Dr. Barwise[1] urges in a report that as soon as the temperature is over 60° F., streets, courts and yards should be systematically watered, as is being done in large towns with encouraging results. At Derby, during 1902, in addition to the water used for the streets, from the second week in July to the first week of September, the Corporation used 1,000,000 gallons of water for flushing the surfaces of courts in the poorer parts of the town where diarrhœa had been most prevalent, with the result that the high incidence of the disease immediately ceased. It is impracticable to carry out the operation on backyards unless they are paved, therefore this improvement, as well as a more liberal supply of water for sanitary purposes, is strongly needed in many districts.

Wood Paving, although it is cleaner than macadam, and less dangerous to horses than asphalt, has been seriously objected to for sanitary reasons,[2] but as the blocks are almost non-porous, and do not readily decay, the objection is not general; no increase of illness in wood-paved as compared with other districts has been noticed.[3] A creosoted wood paving is now largely used. J. Tottrell[4] proposed to mix disinfectants, such as carbolic acid, carbolates, sulphites, or bleaching powder, with the ordinary cements employed in paving roads, basements, walls, etc. The cost would be immense, and the utility seems doubtful.

Urinals require special treatment, on account of the deposit (containing *micrococcus ureæ* and other organisms) which forms from the urine and promotes ammoniacal fermentation. Their sides should be of slate, or of enamelled (not painted) iron; then they can at intervals be washed down with a solution of sulphuric acid 2½ per cent., and permanganate 2 per cent.; this, of course, must not be put into metal pails unless they are tarred. The sides have been sometimes constructed of glass, but they are too liable to fracture, and then the urine penetrates, and putrefies at the back. Well-tarred iron is the next best material, but is easily scratched, and then rusts into holes. Urinal cakes are practically

[1] *Public Health*, July, 1903, p. 611.
[2] *Q. J. San. Institute*, June, 1894.
[3] *Lancet*, July, 1894.
[4] Patent No. 8,317, 1884.

useless, and disinfecting powders are only temporary in their action.

Stables, pig-styes, and cowsheds require to be regularly cleaned, and to be periodically disinfected, like rooms, with removal of the animals, to prevent disease occurring. Some varieties of antiseptic litter have already been mentioned (pp. 17, 97). It is of little use to be perpetually deodorizing with powders. Dryness, ventilation, and cleanliness are better safeguards.

For Cattle Markets and Fairs a cresol disinfectant is probably the best. A description of the chief ones is given at pp. 221-227.

Slaughter-houses are particularly difficult to disinfect on account of the large amount of albuminoid matters present. It has already been noted that it is almost impossible to sterilize blood in the cold. Mercuric chloride and phenol are unsatisfactory because of their action on albumen: chlorine and sulphurous acid are rarely to be recommended: wood charcoal only serves to deodorize, and does not disinfect. Copper sulphate is one of the most useful agents in these places; but cleanliness and rapid removal of offal are the first considerations. Cunliffe and Barlow[1] subject the refuse to heat and destructive distillation. Slaughter-houses for infected or suspected animals are usually situated near seaports, and require special methods of isolation and extra precautionary measures.

Bakehouses, Dairies and the Milk Trade will be alluded to under *Food*, Chapter XIV.

Domestic Animals.—Pigeon and fowl houses, rabbit hutches, and caged animals generally, are a source of danger unless kept scrupulously clean, and occasionally disinfected, with removal of the animals. Dr. A. W. Martin[2] has shown that the cow, the horse, pigeons, fowls and cats have conveyed diphtheria. F. C. Harrison's experiments[3] lead him to the conclusion that the bacillus of bird-diphtheria is not identical with the Klebs-Löffler bacillus of man. The connection of rats with bubonic plague is now well known.

[1] Patent No. 19,967, 1890. [2] *Pub. Health*, June, 1903.
[3] *Dominion Medical Monthly, Toronto*, March, 1903.

Vehicles.—In cases of supposed infection, Sanitary Inspectors are authorized to disinfect without charge, and give a certificate. Cushions and removable fittings are sterilized in a steam oven. Formerly all exposed woodwork was washed with carbolic soap, and carbolated oil was smeared over metal work with the view of disinfecting it and also protecting it from chlorine, which was then evolved inside by one of the methods given on p. 77, and the vehicle was shut and left so for an hour. Sulphurous acid or formalin is now used, and a longer time is allowed.

A systematic disinfection of railway carriages under a uniform system is urgently needed. At the International Congress of Hygiene, Brussels, 1903, it was resolved that (1) Fittings should be arranged to facilitate cleaning and disinfection, with the suppression of loose textile materials, and easy removability of cushions and furniture: (2) Cleaning of surfaces by damp cloths and removal of dust by a vacuum apparatus were recommended: (3) Disinfection must be regular and frequent, apart from any incidence of exceptional disease, and must include (*a*) complete disinfection of removable furniture: (*b*) washing of surfaces and spraying with antiseptics, or efficient fumigation with formaldehyde or other effective agent: high pressure steam at 110°, or dilute hypochlorites, were effective, but were liable to cause damage: (4) Special conveyances are required for the sick and for dead bodies, the latter should be in sealed coffins, and for long distances should be embalmed: (5) An International Commission should be appointed to fix, by methodical experiments, standard methods and regulations to be adopted.

With reference to cattle and luggage waggons the Congress resolved that the former ought to be disinfected after each journey, and the latter after they had carried putrescible or suspected substances, with in each case a previous thorough cleaning. See the valuable reports of Redard, Csatary and Adolph Freund of the practice on French, Hungarian and Austrian Railways. The latter showed that after the most careful cleaning with very hot water, there remained an organic film which required repeated

irrigation with an active disinfectant. He prefers hypochlorites in dilute solution, and uses simple spraying apparatus.

Skins, furs, wool, and hair are sources of infection, owing to the possible presence of anthrax. Machines are now devised for carrying the dust away by fans, and for disinfecting by steam; the trouble is, that the wool will not bear a temperature sufficient to kill the anthrax spores, which are, moreover, very highly resistant to chemical agents (see *Mercuric chloride*, p. 180). So that the only means practicable are cleanliness on the part of the workmen and the use of fans. The Chief Inspector of factories and workshops records 39 cases of anthrax in 1901, an increase of 2 over the year 1900. Arsenic is used in the preparation of furs and skins, but of the chemical disinfectants, formalin seems to be the most suitable for general disinfection of such articles.

Rags are exceedingly dangerous, because they often come from fever-stricken districts, and convey bacteria as well as vermin. Their importation in cholera times is generally prohibited, but as they carry other diseases besides cholera, they are at all times to be regarded with suspicion. It is difficult for steam or heat to penetrate the tight bales into which they are compressed by hydraulic pressure. Parker and Blackman[1] force hollow screws into the bales by means of suitable machinery, and then introduce a disinfectant through the screws, and afterwards air, which displaces any noxious smell. This apparatus is used in America. An improved process has been devised by Paton and Ransom.[2] Conical perforated pipes are first driven into the bales, and then hot air is forced into the bales to heat the interior and prevent the steam, which is subsequently introduced, from condensing. Steam at 10 to 25 lbs. to the square inch is then forced in for fifteen to twenty minutes, succeeded by hot air for ten minutes to remove moisture, and cold air for about the same time to finally cool the mass. It is adapted for cotton and textile goods as well as rags. The disinfection of rags is now

[1] Patent No. 16,539, 1884.

[2] Patent No. 7,735, 1894.

necessary under the new Act of the United States Legislature. All rags used for paper-making must, prior to shipment, be disinfected by one of the following methods:—First, boiling the unbaled rags in water for half an hour; second, exposing them to the action of steam between 100° C. and 115° C. for a similar period; third, exposing them for six hours in an atmosphere of sulphur dioxide, made by burning 3 lbs. of sulphur to every 1000 cubic feet of space; fourth, exposing them six hours in an atmosphere containing 3 per cent. sulphur dioxide gas liberated from liquid sulphur dioxide. By the third and fourth methods the rags must not occupy more than 50 per cent. of the total cubic space.

Disinfection of Air.—This is impossible except in confined spaces. The germs of cholera and of a large number of other diseases are known not to be carried by air, as an exposure to free oxidation in the atmosphere (possibly to ozone in addition to common oxygen) and to light soon destroys the majority of bacteria. In still air the organisms sooner or later settle, especially if the air is damp and the walls are moist. The number is greatest in places where the population is dense and the ventilation defective.

C. Flügge[1] found that dust containing bacteria floats in the air of a quiet room for more than four hours, and the slightest current of air will waft it about. Minute drops of moisture containing bacteria pass into the air even in closed rooms from the ordinary manipulations and float for five hours, and are transported by a current no stronger than 0·7 mm. for a horizontal draught or 0·1 mm. for an upward current, a fact of great importance in regard to the secretions of the mouth and nose. Agar plates become covered with colonies of bacteria at a distance of several yards, from persons speaking loudly and energetically; coughing produced a still more rapid and abundant colonization, while the plates showed no growth when the person spoke low and quietly. He does not consider dry floating dust a serious menace for the infection of wounds during operations, as the staphylococcus aureus and albus in these conditions are

[1] *Zeitschr. f. Hyg.*, xxv., No. 1.

not sufficiently virulent to colonize agar plates; all his experiments in this line were negative. But he emphasizes the danger from the persons present at the operation, as they speak, sneeze or cough. The pyogenic bacteria are frequently found in the mouth of perfectly healthy persons, and have not been attenuated by drying, but are moist and often extremely virulent. Distance from the operating table does not prevent the germ-laden drops of moisture from reaching the patient or some following case, or alighting on the instruments. The patient himself may infect the field by heavy breathing, etc. Mikulicz's "Transcendental Surgery," (gloves and mouth screens) was inspired principally by these experiments of Flügge, with which he was familiar. Percy Frankland's experiments, described at the Eastbourne Health Congress, 1902, confirmed Flügge's results as to the rapid dissemination of organisms by violent emissions of the breath. In ordinary respiration, however, it has been shown by numerous observers, that bacteria are arrested by the moist interior of the nose, and expelled by the ciliary membrane in the mucus, to such an extent that expired air is almost free from organisms, while few of those inhaled reach the lungs.

In addition to micro-organisms, air may contain fragments of carbon, of hairs, fibres of tissues, particles of starch, pollen granules, epithelium, etc. These can be removed by filtration through cotton wool, also in great part as we have seen, by passage over damp surfaces, or by subsidence.

Malaria, as the word, "bad air," implies, was formerly supposed to be due to gaseous emanations from marshes, but is now known to be caused by the microscopic animal parasite, discovered by Laveran and called *Plasmodium malariæ*. This, and many similar diseases which are carried by insects, are dealt with by exclusion and extinction of the latter and not by disinfection.

In addition to the apparatus for the disinfection of air already alluded to, there are a very large number of other inventions, which may be classified as follows:—

1. *Heat.* When polluted air has simply to be got rid of, it can be passed through a furnace if care be taken that it all comes in contact with the heated surfaces. Experiments

with refuse destructors have established that, although a comparatively low temperature is sufficient for killing micro-organisms, a temperature of at least 680° C. is essential for destroying organic noxious vapours. Heated channels are open to the following objections:—(*a*) If the air passes rapidly, there is danger that the central parts of the current will escape without being sterilized, on account of the bad conducting qualities of air; (*b*) the air so treated is rendered unfit to breathe; (*c*) the coils, if narrow, become clogged and coated; (*d*) they are uncertain in action, depending on the working of the stove; (*e*) if made of fire-brick flues or fireclay tubes, instead of iron, they are easily broken in stoking, stirring, or cleaning; (*f*) they have been known to cause fires by passing near woodwork. Nevertheless, a method of this kind is cleaner, cheaper, and more effectual than any chemical disinfection for constant use.

2. *Washing with water;* with or without disinfectants. Numerous apparatus have been designed, with screens, bead-tubes, plates, fans, or bubbling-through arrangements. One of them, Key's screen,[1] constructed of vertical cords interlaced with horizontal copper wires, over which water trickled, was tried in a dense fog in 1893; the air that passed was bright, clear and free from odour, but dust was not entirely arrested, as one would expect from the fact that the channels, though narrow and numerous, were very short. Spray apparatus have been already discussed.[2]

3. *Fumigation,* or mixing with volatile disinfectants, has also been fully dealt with.

4. *Air Filters.* Cotton wool strainers are used at the Houses of Parliament: they can be made efficient but require considerable motive power to impel the air. Asbestos filters can be renewed by burning, but are only practicable on a small scale. Ozonising the air after filtering and then passing it into rooms[3] suggests danger from irritant effects on the lungs. Sodium peroxide has been proposed for removing carbonic acid and renewing oxygen in confined spaces, and in sick rooms, but there is no disinfecting action.[4]

[1] *Hygiene,* May 13th, 1893.

[2] See Index, *Spraying of Rooms.*

[3] J. Harris's French patent 320,661 of 1902.

[4] *Comptes rendus,* cxxviii., 361.

Water. The methods of purification described in Chapter II. were mainly directed towards the elimination of bacteria from water. Their *destruction* can be accomplished in two ways, either by bringing the water to a temperature capable of killing the organisms, or by introducing a chemical re-agent effecting the same end. The practical difficulties of these methods as applied to drinking water have to a great extent been solved by the special attention which has been given to the subject during the last few years.

I. *Sterilization by Heat.* Boiling is, of course, an efficient means on a small scale, but the expense is prohibitive when large quantities of water have to be regularly dealt with. In India the Larymore boiler has been largely used and found efficient, but the taste of the boiled water is often objected to, as the liquid not only is flat and free from dissolved gases, but has frequently a burnt flavour from overheated organic matter. A successful heat-sterilizer must, therefore, be so designed as not only to yield a water which is bacterially pure, but to insure the preservation of the natural flavour and gases of the water, and, further, some means of regenerating the heat required for effecting the sterilization must be included. One of the earliest methods for carrying out this object consisted in heating the water to a temperature of about 115° C. in a closed vessel (when the natural gases are not evolved, nor are the salts deposited to any considerable extent), and using the outgoing water for warming that entering the boiler by means of interchanging coils. In such a system the heated water is not exposed to the air, and is therefore kept free from any subsequent contamination. At Brest, in 1892, apparatus on these lines by Rouart and Geneste-Herscher & Co. were officially tested. Later Professor Vaillard of the Pasteur Institute in Paris, and Mons. Desmaroux devised similar plant, so arranged that all the water passed through a superheater in which it was subjected to a minimum temperature of 113° C. for about five minutes. Connected with the superheater was a temperature exchanger made of a double series of spiral compartments, which cooled the sterilized water to within a few degrees of the supply. This apparatus has been used at the Sanatorium de St. Trojan, in Paris. When made on a large scale, the economy in fuel is greater, and at

Tsaritzine on the Volga, a large installation is heated from a common source, and there produces enough sterilized water for a population of 10,000.

A difficulty in all such apparatus, however, is met with in the deposition of salts from hard waters in the temperature exchanger, and as, for perfect cooling, the tubes or compartments must necessarily be small, there is danger of such tubes blocking with the deposit, unless facilities for frequently cleansing are provided. More recently the heat sterilization of water has been effected in plant in which the water is not heated under pressure, but is brought to the boil, and at once passes over a weir into a temperature-exchanger. Since the water only boils for a few seconds, it retains most of its original gas and taste, and the apparatus can be so constructed that it is impossible for any water which has not been boiled to pass into the cooler. The Forbes apparatus is designed on these lines.[1] A constant level in the tank placed above the exchanger is insured by a float-actuated valve which maintains the water-level in the boiler slightly below a cup placed therein. The valve-box therefore regulates the flow of the water irrespective of the pressure on the surface, in a similar manner to the bird-fountain or aerostatic feed-apparatus used when a constant level is required with a small volume of water. The sterilizer operates at a rate which will be dependent upon the size and intensity of the flame of the burner, as the water will boil over the cup at different rates. It is obvious that although the speed in a given apparatus depends entirely upon the rate of boiling or the heat applied, the temperature of the sterilized water will correspondingly vary if the same cooler be always used. In the United States, I am informed that nearly a thousand army sterilizers of this pattern are in use. They are constructed of copper and brass, block tin-lined and nickel-plated: the nett weight is 55 lbs., and with the field case 100 lbs. The output with a Swedish petroleum lamp is 25 gallons per hour of sterilized water, about 7° C. warmer than the feed, or a less difference if it be worked at a slower rate. The oil tank holds 1·37 gallons, sufficient to operate the apparatus for 15 hours. It would seem quite practicable to build this sterilizer in any size, even to the

[1] U.S. patent, December 13th, 1898.

extent of sterilizing the water supply of a city or town, at a stated cost of from 13/9 to 14/- per million gallons, including interest on the plant, fuel and labour. In such apparatus in America, 1 lb. of coal has sterilized from 2,000 to 5,000 lbs. of water. This sterilizer has claims as follows:—

(1) A source of water supply having a level maintained below that required for causing the water to pass entirely through the apparatus.

(2) The application of heat to a part of the water in the apparatus at the point reached by gravity (due to the maintained level in the source of supply) until ebullition is produced, thereby causing the water to rise and pass through the remainder of the apparatus; and

(3) The transference of the heat from the hot water passing from, to the cold water passing to, the point where the heat is applied. Other sterilizers used in the United States are the Kny-Scheerer and the Maignen; in the Argentine Republic a design due to Von Siemens has been tried. In this country the Lawrence sterilizer has been in use for some time at Guy's Hospital and elsewhere, and accomplishes the object somewhat differently from the Forbes apparatus. It has a vertical boiler in which are placed depositing-trays of iron above the water line, and a series of plates termed "locators," in the boiling water. The inflow passing downwards is met by the steam produced below, and is thus progressively heated until it attains the highest temperature, and the most violent ebullition, in the lowest compartment. The gases in solution are expelled, and the carbonates of lime and magnesia are almost entirely deposited as a friable scale upon the trays and locators, which are removed from time to time for cleaning or replacement, while the amount of sludge at the bottom can be blown out from time to time without trouble. The softened liquid then passes upwards through an outer division of the cylinder, to an interchanger where it gives up its heat to the raw inflowing water, and finally issues at a temperature depending upon the rate of boiling, so that the heat is in this way almost wholly recovered. Very little attention is required, and trouble with re-agents is avoided. When used for softening boiler-feed water, it is found best to cool only to 17° C. above the inflow to obviate the loss by radiation involved in storing or transferring hot water. As already mentioned in

Chapter II., organic matter is removed to an appreciable extent whenever softening of a water takes place, so that sterilization by heat, besides killing bacteria, generally renders the liquid organically purer. In common with the Forbes pattern, the rate of flow is regulated by the heat applied, but it is clear that without special provision, unsterilized water can pass through into the heat chamber, and so contaminate the supply. By inserting in the boiler a metal plate fitted to a carefully adjusted valve, the steam produced in the boiler can be made to regulate the flow of the water so that to a certain extent the apparatus can be made as automatic as the Forbes plant.

In a portable sterilizer and softener on these lines, now being tested for use in the British army, the boiling vessel has an outer case of galvanized iron, about $16\frac{1}{2} \times 6\frac{1}{2}$ in., and 32 in. high, with an opening at the bottom into which is slid an intensive three-burner oil lamp having a great heating power; the chamber is ventilated by holes punched all round, and also by three flues passing right through the centre. The upper part contains an inner vessel holding four trays, beneath which are three cylinders each containing a set of "locator" plates having an opening down the centre which enables them to be passed over the three flues. The water, on reaching the bottom, passes up outside the three cylinders, and is taken off at the proper level into the heat interchanger, which is a galvanized iron box, 20 × $6\frac{1}{2}$ in. × 30 in. high. It contains three corrugated cylinders of hard rolled copper connected into a collecting box at both top and bottom; the outlet pipe, which is brought up to the top to ensure the vessel being always full of water, is, for the sake of compactness, fixed inside the tank. The maximum output is 50 gallons of water per hour when working with petroleum, and the apparatus, weighing about $1\frac{1}{4}$ cwt., can be carried on a mule's back. It is proposed to use collapsible tanks to feed and to receive the sterilized water.

Results obtained in working different forms of heat sterilizers in my own laboratory, show that even with very varying rates of flow, sterile water can with care be usually ensured. At the same time, when working rapidly, the amount of dissolved gas in the treated water is much reduced, but the fault can be remedied, if required, by storing in carefully cleaned vessels protected by cotton wool. Maiche's

heat sterilizer is somewhat similar and in its army form weighs 278 lbs. and yields 22 gallons per hour, but Major Macpherson considers it too bulky for field service.[1]

The chief objection to heat sterilizers at present is the blocking up of the interchanger when used with dirty or hard waters, and in army service the difficulty of providing fuel. Where no economizing interchanger is included, as in the recent suggestion of Dr. Leigh Canney, not only the cost, but the difficulty of supplying the fuel required must render the system prohibitive. Further, heat sterilizers of non-pressure types clearly do not ensure the destruction of spores, and therefore can only be used as a precaution against cholera and typhoid, and other non-spore-bearing pathogenic organisms. It is fortunate that these two diseases are amenable to prevention by the simpler forms that I have described. With candle filters (p. 20) it is clear that theoretically the transport problem is reduced to a minimum, as there is no expenditure of any material during the period of use, so that the weight required is simply determined by the actual filter itself and necessary accessories. On the other hand, for small units and individual troopers, when away from their base, the weight of even a small pocket filter is considerable, and the advantage then lies in some form of chemical sterilization.

II. *Chemical sterilization* is mainly to be regarded as an emergency method. The considerable total expense for even the cheapest chemical, apart from the labour and trouble involved, must necessarily render the operations costly. Under special circumstances, however, this method may become useful and even necessary.

Oxidizing agents have generally been favoured on the ground that oxygen was the natural purifier, but we have seen that oxidation is only a part, and not the most essential one, of natural purification. Their great disadvantage is that they are largely consumed by easily oxidizable substances which may be physiologically harmless, before an excess can be established to act on bacteria; hence the water must be prepared beforehand by removal of most of the organic matter. The variations in the amount recorded as

[1] *Public Health*, June, 1901.

necessary by different observers is due in great part to this cause.

It is obvious that for drinking water only such re-agents are available as do not affect its wholesomeness or palatability. In water supplies, however, from which the greater part of the organic matter has been removed by some preliminary process, the quantity of some oxidizing agents required is so exceedingly small that it would have no injurious effect on the consumer. Among these substances the manganates and permanganates have long been popular. Potassium permanganate was employed on a large scale by Lereboullet for the drinking water of the soldiers in the Franco-German war of 1870; at that time it was not a question of destroying the organisms, but solely the organic matter present. In India it has been widely used for purifying wells and tanks, these being regularly "pinked" by officials as a defence against cholera,—Hankin considering it to be a specific for cholera bacilli;[1] recent reports on the efficiency of the practice have, however, been unfavourable. Its action on bacteria has been examined by numerous observers. Koch[2] states that it is effective only in concentrated solutions. Calvert[3] found 1 in 125 necessary to prevent growth in bouillon for six days. Miquel states that 3·5 grammes were required to sterilize one litre of beef tea, or one in 286. Demarquay, from surgical experience, considered that one in 1,000 "disinfected very well, but its action was rapidly exhausted, and it did not prevent the secretions from retaining their virulence." Vallin was of similar opinion,[4] also Blyth[5] and Klein.[6] Dr. A. H. Burgess found that one in 40 was required to destroy B. coli communis in one hour.[7] An experiment by the author has been already described (p. 351).

Lepeyrère, at the Paris International Congress of Hygiene in 1900, suggested the use of a mixture of potassium permanganate, sodium aluminate, and sodium and calcium carbonates for the purification of water in campaigns. After standing a few minutes the water was passed through "purified peat fibre" mixed with manganese dioxide. The

[1] *Brit. Med. Journ.*, March 16th, 1895. [2] *Mitth. Kais. Ges.*, 1881.
[3] *Brit. Med. Journ.*, March 16th, 1895. [4] *Désinfectants*, 1882.
[5] *Proc. Roy. Soc.*, 1886. [6] Stevenson and Murphy's *Hygiene*, 1893, p. 61.
[7] *Lancet*, June, 1900.

process was examined by Dr. A. Warner[1] with water infected with B. typhosus; even when filtering slowly it did not get rid of the pathogenic bacteria.

Ozone has the exceptional advantage of being easily obtained everywhere from atmospheric oxygen, and recent progress in ozone generators and electric supply lead to the belief that this gas may be economically produced. In several directions it has been used for public supplies on a large scale, and it promises to be further extended as a "finisher" in the sterilization of water. The chief difference between the action of ozone, O_3, and of atmospheric or ordinary oxygen, O_2, is that the latter will not act on most varieties of organic matter without the help of organisms,—either direct, in their processes of life, or indirect, through a special class of enzymes, called oxydases, that some of them produce. In the sterilizing function of ozone only one-third of the oxygen actually contained in it ranks as "available" oxygen. The gas attacks metals, india-rubber, gutta-percha, and wood, and is thereby itself destroyed, hence apparatus for its production, storage, or conveyance, must be constructed of stoneware or glass, or, less advantageously, of protected metal. The air to be ozonised is first freed from dust by cotton wool strainers, then dried, to avoid the formation of nitric acid, and passed through a cooled space traversed by a silent electrical discharge. Sparks should be avoided, as heat re-converts ozone into ordinary oxygen. To obtain a strength of 7 per cent. (the highest mentioned) was found by M. Chassy to cost in electric energy 90 times as much as half per cent., so that if economy be considered, it is best only feebly to enrich the oxygen, while accelerating the circulation of gas. Ozonisers are of a number of forms.

Baron Tindal, about 1896, proposed to the municipality of Paris, to sterilize, by means of ozone, 5,000 cubic metres (1,100,000 gallons) of crude Seine water daily. His first experiments were made at Oudshoorn, Holland, in 1893. The system was installed experimentally in Paris, Brussels, and Ostend, and was proved by the reports of Dr. Van Ermengem and others to sterilize at a reasonable rate canal and other waters which had been previously filtered. It was adopted officially for limited supplies in several places in France and Belgium. The machines used in the trials at Brussels were Morley-Brush alternators of 100 volts and 100

[1] *Public Health*, July, 1901, p. 704.

Chemical.	Effective dose Pts. per 100,000.	Subject of trial.	Time.	Effect.	Observer and reference.	Remarks.
Ozone	9	Anthrax spores	10 min.	Sterile	Ohlmüller, Arbeit. Kais. Gesund, 1892, viii.,	Ozonised air bubbled through the liquids
,,	5·8	,, bacilli	,,	,,	,, ,, ,, ,, [p. 229	
,,	1·95	Typhoid ,,	,,	,,	,, ,, ,, ,,	
,,	1·8	Cholera ,,	,,	,,	,, ,, ,, ,,	
,,	8·4	River Spree water	,,	,,	,, ,, ,, ,,	
,,	15·6	Sewage	1 hour	Not sterilized	,, ,, ,, ,,	
,,	·4 to ·6	Very foul Rhine water, filtered	..	86·5 to 100 per cent. of the samples were sterilised	Van Ermengem, Ann. Inst. Pasteur, 1895, ix., p. 673	
,,	·03 to ·04	Brussels' water supply	5 to 10 min.	All sterilized	Van Ermengem and Gérard's report to Belgian Government, 1897	
,,	1·72	Raw water, 1,250 bacteria per c.c.	..	Sterile	Th. Wehl., Centr. Bakt., 1899, xxvi., p. 15	
,,	·05	Water purified by metallic iron (Anderson)	..	Bacteria reduced 99 per c.c.	,, ,, ,, ,,	
Hydrogen peroxide	10	Polluted water	24 hours	Usually sufficient to sterilize	Van Tromp, Apoth. Zeit., 1890, p. 485	
,,	100	Cholera and typhoid bacilli	,,	Bacilli destroyed	Altehoefer, Centr. Bakt., 1890, viii., p. 129	
Chlorine	4	Water	..	Growth of bacteria suppressed	Bucholtz, Archiv. Exp. Path., iv., p. 180	Added as chlorine water
,,	20	,,	..	Sterile	Mean of several observers	,, ,,
Hypochlorous acid	·3 to ·36 active Cl	Effluents	..	Bacteria reduced from innumerable to 10-50 per c.c.	Kanthack, 1898	Added as electrolysed brine
,,	1·77 ,,	,,	14 min.	Sterilized	Rideal, 1898	,, ,,
,,	40 ,,	Typhoid and cholera bacilli	5 min.	Sterile	Nissen, Zeit. f. Hyg., viii., 1890	Added as chloride of lime
,,	17 ,,	,, ,, ,,	2 hours.	,,	Bolton	,, ,,
,,	300 ,,	,, ,, ,,	,,	,,	Boyce, J. Soc. Chem. Ind., May, 1896	Added as chloros (sod. hypochlorite)
,,	50 ,,	Non-sporing bacteria	5 min.	,,	Klein, *Lancet*, Nov. 28th, 1896	,, ,,
,,	100 ,,	Spore-bearing ,,	1½ hours	,,	,, ,, ,,	,, ,,
,,	2·4 ,,	B. coli communis	15 min.	,,	Thompson Yates Laboratories, Liverpool, *Sanitary Record*, Aug. 24th, 1900	,, ,,
,,	2500 ,,	Anthrax spores	30 min.	,,	Clayton, J. Soc. Chem. Ind., May, 1896	,, ,,
,,	5 to 10 ,,	Street waterings	..	Growths inhibited	Parkes, *Lancet*, Dec. 9th, 1900	,, ,,
Chloride of lime	11·	B. coli communis	1 hour	Sterile	A. H. Burgess, *Lancet*, June 23rd, 1900	Added as alkaline solution
Chlorine peroxide	·08	Spring water	Immed. after	,,	Bergé. Ogier, Report to French Government, 1900	
,,	·3	Seine water, filtered	2 hours	From 192,000 bacteria per c.c. to very few	,, ,, ,,	
,,	2·38	Coli and typhoid	3 hours	Sterile	,, ,, ,,	
Bromine	6·	Water	5 min.	,,	Schumberg, Pharm. Centr., xxxviii., p. 239	Followed by 9·5 parts hyposulph. and 4 pts. sod. carb.
Iodine	20·	,,	..	Growth suppressed	Bucholtz, *loc. cit.*	Added as iodine water
,,	1·	,,	..	Rendering water potable	Allain, Marseilles	,, ,,
Iodine trichloride	100·	Cholera, typhoid, etc.	5 min.	Sterile	Traugott, Zeit. f. Hyg., 1893, p. 427	In aqueous solution
Cuprous chloride	0·5	Elbe water	6 hours	,,	Krohnke, 1893	Mixed with ferrous sulphate, then lime and sand filtration
Sulphuric acid	50·	Cholera	15 min.	,,	Stutzer. Zeits. f. Hyg., 1893, p. 116	
,,	20	,,	24 hours	,,	,, ,, ,,	
Sodium bisulphate	176 ($=72\ H_2SO_4$)	Typhoid	15 min.	,,	Parkes and Rideal, 1901	Followed, if necessary, after 15 min. by sod. bicarb.

amperes, with 200 complete periods. The current was sent through a Schneller's transformer, then through a fluid resistance to an apparatus through which a stream of dried air passed at a rate of 40 litres (9 gallons) a minute. The ozonised air, containing 3 to 4·3 grammes of ozone per cubic metre was led into the water at the rate of about 2,400 litres of air to 25,500 litres of water per hour. Prof. Leon Gerard found that "for every gramme of ozone an average of 250 watts was required." He estimated that the gross cost would not exceed 0·45d. or nearly ½d. per 1,000 gallons of water purified, and might be considerably reduced. This does not include the cost of any preliminary treatment which, however, would be necessary under all systems.

In 1898, Siemens and Halske erected an experimental plant at Martinikenfelde, near Berlin, and larger installations are now in use for the towns of Wiesbaden and Paderborn.[1] As usual, it is found necessary to first remove coarser impurities by a quick filter. At the first place mentioned the Siemens apparatus has one-square-metre plates working with 8,000 to 12,000 volts, and generating 20 to 25 grammes of ozone per horse-power hour, at a concentration of 2½ to 3 grammes per cubic metre. The air then passes upwards through a tower filled with flints, and meets a descending current of water of 10 cubic metres (353 cubic feet) per hour. The original water from the river Spree showed 100,000 to 600,000 organisms per c.c.; the effluent was sometimes sterile, and never contained more than 2 to 0 organisms per c.c. The total cost is estimated at about 2¾d. per 1000 gallons of water purified, which is much higher than that of Tindal. That the water is not always sterilized may be due to the fact that the ozonisation is less than the amount of 4 grammes per cubic metre which Van Ermengem found to be effective.

Marmier and Abraham's apparatus, installed at Lille in 1898, has a plate ozoniser with cooled electrodes, working with 40,000 volts, and the water is sterilized as above in a masonry tower. The Commission who approved of the apparatus and its results reported that only a few spores of highly resistant and harmless *B. subtilis* were left, and that these disappeared on about 12 hours storage, the water remaining sterile in the air for four days, though showing

[1] *Zeits. f. Elektrochem.*, November 14th, 1901, and Nov. 27th, 1902.

no trace of ozone a few minutes after issuing from the apparatus. No antiseptic compound was formed, as water bacteria were not inhibited when added to the liquid after treatment. The report concluded that of the few organisms which escape destruction in the tower, nearly all succumb after some minutes in the reservoirs. The only other alterations in the water were a decrease in the organic matter and an improvement in physical character. Proskauer states[1] that for reasons unknown to him, this installation has been abandoned, but another, still at work at Schiedam, near Rotterdam, is said to furnish twenty cubic metres (4,400 gallons) of sterilized water per hour. At Moscow, Russia, an experimental apparatus of this kind was installed in 1901 for purifying the water supply at a stated cost of 0·3d. per 1,000 gallons. For a purifier by Clark, Philadelphia, see *Electrochem. Ind.*, February, 1903.

Froelich, about 1890, proved that ozone destroyed micro-organisms, and that its action was most effective in presence of moisture. He showed[2] that ozonisation sterilizes water, oxidizes nitrites and sulphuretted hydrogen, and throws down iron as ferric hydroxide, and made the important suggestion that ozone should follow filtration. About the same time Kowalowski and Krukowitsch, in Russia, and Christmas in Paris, investigated its bactericidal power. Ohlmuller, in 1892,[3] found that water from the River Spree was sterilized in 10 minutes by 86.6 milligrammes of ozone per litre; sewage was not sterilized in an hour by 156·3 milligrammes; but distilled water to which bacteria in great numbers had been added, was sterilized most easily, anthrax, typhoid, and cholera bacilli being killed in 2 to 10 minutes, proving that where water was not too contaminated with organic impurities, ozone destroyed completely these pathogenic bacteria. Ransome and Foulerton, in 1903,[4] even succeeded in killing bacteria in milk. Other results are summarized in the Table (p. 366).

Hydrogen Peroxide.—The liquid H_2O_2 is similar in action to ozone, breaking up into water and an atom of free active oxygen; it is, in fact, believed to be produced in the ozonisation of water, and may account for the long continuance of the sterility which we have seen the

[1] *Biochem. Centralblatt*, 1903, I., 209.
[2] *Electrotechn. Zeit.*, xxvi., 1891
[3] *Arbeit. Kais. Gesund.*, viii., 229.
[4] *Proc. Roy. Soc.*, vol. lxviii., Feb. 14th.

Commissioners at Lille observed. The results of Van Tromp and Altehoefer are given in the Table. The balance of recent researches have proved that one in 1,000 is necessary, and its cost and instability, the impurities of the commercial article, and the difficulties of transport of large quantities of a liquid, interfere with its use for sterilizing water.

Sodium Peroxide is a powerful oxidizing agent which generates H_2O_2 when dissolved, and being a solid, is free from the last-named objection. It has for some time engaged my attention as a sterilizer for water, and I have made a series of laboratory experiments on its use, either alone or in addition to the usual softening agents such as soda or lime. It has the advantage over these, of giving rise in the water to an oxidizing body which has a specific germicidal effect on the bacteria present. Where the hardness is moderate, sodium peroxide can be used alone, and then has the dual function of precipitating the lime and magnesia together with, as we have seen, a large proportion of the organisms and organic matter, and of inhibiting or killing by means of the hydrogen peroxide produced, any bacteria remaining. In hard waters the hydrogen peroxide required for sterilization is less than the amount produced from the quantity of sodium peroxide that would be necessary for softening, and it is, therefore, more economical to admix the re-agent with cheap softeners not possessing specific germicidal power. As by combination with softening so much of the organic matter is removed, the action of the hydrogen peroxide on the bacteria is better ensured. With the same object, where the organic matter is high, partial softening by ordinary methods can precede the addition of sodium peroxide. This process has the further advantage that the final effect is only a slight addition to the natural sodium salts, and that acid moorland waters are neutralized and bleached, and their plumbo-solvency removed. Appended are two examples of satisfactory results that I have lately obtained:—

A. London tap-water, containing an average of 30 organisms per c.c.; permanent hardness 3·71 parts per 100,000. To separate quantities were added (1) 3 parts per 100,000 caustic soda, (2) 3 parts per 100,000 of sodium peroxide.

B. Somewhat impure water, containing 93 organisms per c.c.; permanent hardness about 4 parts. (1) 3 parts per 100,000 of caustic soda, (2) 1·5 caustic and 1·5 sodium peroxide.

Blanks were mounted in each case, and all the waters after the first shaking were allowed to settle, in series A at about 10° C., in series B at 18°. The number of organisms per c.c. were as follows:—

	A.			B.		
Hours.	Blank.	(1.)	(2.)	Blank.	(1.)	(2.)
1	31	28	11	115	94	62
3½	27	18	1	103	100	34
24	19	16	0	173	117	2

(1) Shows the result of softening alone, (2) that of softening with the aid of sodium peroxide. The multiplication of organisms in B (1) at the higher temperature is in accordance with what we have previously noticed in simple softening.

Lime alone is slightly antiseptic, as was shown by Liborius, Vallin, and Pettenkofer; later, its action on typhoid and dysenteric discharges was studied by Kitasato and Pfuhl, Richard, and Chantemesse, but in all these experiments the quantity was considerable, 400 parts per 100,000. This is more than would dissolve. I have found that saturated lime water, containing 143 parts of slaked lime per 100,000, apparently killed *typhosus* in half an hour. Burlureaux, by adding it in decreasing quantities to polluted waters, concluded that lime alone could not sterilize without rendering the water unpotable. He believed that the organisms were ordinarily "stupefied," not killed, and this was afterward verified by P. Frankland, Kruger, and others who noticed the subsequent re-multiplication.

The Halogens.—Chlorine, bromine, and iodine (see Chap. IV., p. 77) are amongst the most powerful of germicides. As a rule, they cause oxidation by combining with the hydrogen of water, and liberating oxygen in the "nascent" state, while they also have a tendency to replace hydrogen in organic or other substances containing it, or to

form additive compounds. In consequence of the combined actions they (1) deodorize the gases of putrefaction, sulphuretted hydrogen, phosphuretted hydrogen, ammonia, and compound ammonias; (2) lessen, by bleaching, the colour of water; (3) decompose ptomaines and other organic matters; (4) form antiseptic substances inimical to bacteria, but in small quantities innocuous to higher life; (5) precipitate the albuminoids, therefore attack the bodies of organisms themselves. In many of these actions light is necessary, and heat is also favourable. As with nearly all chemical sterilizers, unless the water first undergoes a partial purification, the great part of the re-agent is wasted in attacking comparatively inert matters. Krönig and Paul in 1897 found that the disinfecting power of the series Cl, Br, I, decreases in the ratio of increasing atomic weights, 35·4, 80, 127, but that it varied with the kind of organism and the conditions.

Chlorine water is not convenient to use, on account of its instability, its strong odour and corrosiveness, and its small content of chlorine, 0·63 per cent. by weight. This has led to the employment in preference of the *Hypochlorites* derived from hypochlorous acid, HClO. In commerce they always contain chlorides, which are practically inert; the "available chlorine" being that portion which liberates oxygen on reaction with water; an excess of lime or soda has always been present for the sake of stability, but a pure hypochlorite of soda has recently been obtained. These compounds deteriorate when stored, especially in presence of air, moisture, and light, therefore their strength must be controlled by analysis. In "chloride of lime," the available chlorine is expected to be 33 to 34 per cent.; in "chloros" solution, a sodium hypochlorite, it is regulated to 10 per cent. The former, although the cheapest, is generally unsuitable for waters, as it leaves a quantity of insoluble matter, spoils the taste, and increases the hardness. Before 1884, and again in 1887, it was used in the River Thames, but it was shown that "unless large and continuous doses were kept up," the foulness of the stream was not controlled. All hypochlorites in the small quantities that can be used for drinking water, are decomposed by the natural carbonic

acid, giving free hypochlorous acid, which in its turn may break up into hydrochloric acid and oxygen.

$$2NaClO + H_2O + CO_2 = Na_2CO_3 + 2HClO$$
$$HClO = HCl + O$$

The carbonate of soda acts in the usual manner as a softener, precipitating carbonate of lime.

Hünermann and Deiter[1] advocate the use of sodium hypochlorite in the proportion of four parts available chlorine per 100,000, with ten minutes contact, for typhoid and cholera, removing the excess by sodium sulphite. V. Rabs,[2] on the other hand, considers from his experiments, that with the quantities of chlorine prescribed by earlier investigators the time of contact must be extended to at least 30 minutes for successful sterilization.

In the Webster, Hermite, and Electrozone processes, hypochlorous acid is formed by electrolysis.

The effects of hypochlorous acid are shown in the Table, the variations being explained by different circumstances of time, temperature, light, acidity, or alkalinity, nature of the substances in solution, and character of the organisms. Although useful as "finishers" for polluted water, the hypochlorites are expensive, and are apt to communicate unpleasant odours and tastes.

Chlorine Peroxide.—ClO_2 is one of the most energetic of sterilizers, and was first used for waters by Bergé.[3] It is prepared by the action of sulphuric acid on potassium chlorate, the resulting gas being passed into water.

$$3KClO_3 + 2H_2SO_4 = KClO_4 + 2KHSO_4 + 2ClO_2 + H_2O.$$

This is easily and safely effected by an apparatus described by M. Howatson.[4]

Although the solution is very fatal to bacteria, it is far milder in odour than chlorine or hypochlorous acid, and seems innocuous to animals.

[1] *Chem. Centr.*, 1901, 2 [4], 318. [2] *Hyg. Rundschau*, xi., 1085.
[3] An account of his experiments is given in *Ann. Trav. Publ. Belg.*, 1898, 369.
[4] Also see English patent 4917 of 1898.

For the same reasons as with previous chemical re-agents, to work economically it is necessary to subject the water to a preliminary treatment, which in the Howatson-Bergé process as operated at Brussels and Ostend, consists of softening and mechanical filtration. At the latter place the potassium chlorate used in the preparation is 2 grammes per cubic metre of water, which would give theoretically 0·74 grm. of ClO_2, or 0·74 parts per 100,000. Van Ermengem, in 1898, found that the canal water, with 890 to 23,000 organisms per c.c., after the treatment in 14 cases was sterile, and in five contained one or two colonies of the resistant and harmless *B. subtilis* or *ramosus*. At Lectoure, in Southern France, the town supply, drawn from the river Gers, and seriously polluted with sewage, has been for many years purified by this process. Dr. Ogier reports that the river water contains 21,000 organisms per c.c. before, and only 7 or 8 after the treatment with peroxide. Other results are given in the Table. In my own experiments, I found that 2 parts of chlorine peroxide per 100,000 did not kill *B. typhosus* in a vigorous pure culture in two hours, but that 5 parts killed it in half-an-hour. These results are comparable with Dr. Ogier's (see Table), but obtained under somewhat different conditions. The slight excess of ClO_2 rapidly disappears from the water.

Bromine has been frequently proposed for sterilizing water, the objections being the dangerous properties of liquid bromine, and the taste and physiological action of the bromide produced. In 1897, several practical suggestions were made. Altmann patented a solution of bromine in potassium bromide, using 4 parts Br. per 100,000 of water acting for 5 minutes, and removing the excess by ammonia. The solution has the inconvenience of bromine, and is more bulky; the use of a potassium salt has also disadvantages.

Schumberg, of the German Army, recommended free bromine, 6 parts per 100,000, for sterilizing water in expeditions, on ship-board and in cases of suspicion, stating that sterility was obtained in five minutes. He removed

the excess by a tablet of sodium sulphite and mannite, the latter probably to conceal the taste; later sodium thiosulphate and bicarbonate were employed. The method was tried in the Soudan campaign of 1898, but the difficulties of transport of liquid bromine in glass bulbs militated against its use. In the same year Braithwaite proposed to avoid this by adopting a solid mixture of a bromide and bromate followed by acid sulphate of soda to liberate the bromine, but the method does not seem to have been tried on a large scale. The quantity he recommended was sufficient to give one grain of bromine per quart, or 5·7 parts per 100,000, practically the same as Schumberg used. In my own experiments I have found that two parts of Br per 100,000 kills *B. typhosus* in less than half an hour. Schüder[1] has come to the conclusion that Schumberg's process fails almost completely in the quantities suggested by him, and therefore agrees with the opinion expressed by Dr. Parkes and myself in our paper at the Epidemiological Society, in January, 1901.[2] The fact, moreover, that there must necessarily remain in the water a residue of bromides which are known to have a marked physiological effect, cannot be considered either natural or safe, and should preclude the recommendation of bromine for sterilization of water for drinking. A similar remark applies to iodine (which was used for the same purpose by Allain at Marseilles), to iodine trichloride and cuprous chloride, which I have mentioned in the table, and to many other compounds that have at various times been proposed. My own experiments with iodine trichloride showed that with two parts per 100,000 *B. typhosus* was alive after 20 hours, but that five parts killed it in half-an-hour.

Sterilization by Acids. The observations of Koch, Stutzer, Ivanoff and Kitasato have already been given (p. 136). The latter's results with *B. typhosus* in nutrient media, have been summarized by Horrocks in the following table:—

[1] *Zeits. f. Hyg.*, xxxvii., 306.
[2] See also a paper by Dr. H. Frazer, *Pub. Health*, September, 1902, p. 721.

	Per cents. of re-agent.		
	Growth.	Growth restrained	No growth.
Acids—			
Sulphuric acid	0·049	0·065	0·08
Hydrochloric acid	0·1	0·158	0·2
Nitric acid	0·1	0·157	0·2
Sulphurous acid	0·09	0·2	0·28
Phosphoric acid	0·15	0·224	0·3
Acetic acid	0·2	0·255	0·3
Carbolic acid	0·2	0·258	0·3
Formic acid	0·22	0·278	0·34
Oxalic acid	0·23	0·285	0·366
Lactic acid	0·27	0·36	0·4
Tartaric acid, Citric acid, Malic acid	0·338	0·384	0·476
Tannic acid	1·3	...	1·66
Boric acid	1·5	2·0	2·7
Alkalies—			
Caustic lime	0·0725	0·0805	0·0966
Caustic potash, Caustic soda	0·1	0·14	0·18
Ammonia	0·148	0·2	0·3
Lithium carbonate	0·514	0·6	0·666
Potassium carbonate	0·566	0·74	0·81
Barium hydrate	0·65	0·83	1·00
Ammonium carbonate	0·72	0·845	1·0
Sodium carbonate	2·00	2·2	2·47
Salts—			
Potassium iodide	6·66	8·6	9·23
Potassium bromide	8·0	9·23	10·37
Potassium chloride	9·1	10·6	10·2

In these experiments broth and gelatine media were carefully neutralized before adding the substances, then inoculated with typhosus and kept at room temperature, sub-cultures being taken at 4 or 5, and at 10-15 hours.

Very different results are obtained, however, when water free from organic matter is employed instead of nutrient media. Thus, ·096 per cent. of caustic lime to kill typhoid in strong broth is reduced to ·0074 per cent., or less than one-tenth, when the broth is diluted with 15 times its volume of distilled water. Similarly in bouillon containing less than 1 per cent. of peptone, cholera vibrios are killed by ·01 per cent. hydrochloric acid in half an hour, but require four times this quantity in the presence of 2 per cent. of peptone. It would therefore appear that chemical re-agents, whether they possess oxidizing properties or not, are more efficient

as sterilizers when the water to be treated is comparatively free from organic matter.

My own results with some of these substances in impure water, inoculated with varying amounts of typhoid and kept at room temperature, are :—

Re-agent.	Per cent.	Time (hours).	Results.
Sulphuric acid	·025	20	killed
,, ,, ...	·030	(*a*) ½	alive
		(*b*) 1	alive
		(*c*) 20	killed
,, ,, ...	·035	½	,,
Sulphurous acid	·030	20	,, (alive at 1 hour)
Caustic soda	·050	½	alive

The organic acids, like tartaric, citric, and acetic, also possess this property; and in 1893, the use of tartaric acid for purifying water, in conjunction with a filter, was patented, and its use has recently been suggested in Italy for sterilizing salads before consumption. Dr. Christmas, in 1892, showed that citric acid, although fatal to the cholera bacillus when used in the proportion of 8 parts in 10,000, did not destroy the bacillus of typhoid in a less strength than 1 in 1,000. It may be that lemon juice and vinegar, as dietetic adjuncts in salads and uncooked shell fish, have further been extremely useful in minimising the dangers of typhoid derived from such sources. These facts, coupled with the alarming outbreak of enteric fever in South Africa among our troops, induced me, in conjunction with Dr. Parkes,[1] in the autumn of 1900, to specially study the effect of dilute acids when added to drinking waters infected with typhoid. We doubted whether filters or boiling apparatus could be made to accompany a rapidly moving column, and thought that it would be possible to find some acid material which would destroy the virulence or inhibit the growth of the *B. typhosus*, whilst not rendering the water unpalatable, or injurious to the health of the consumer. It was also necessary that the re-agent should be rapid in its action, and we fixed 15 to 30 minutes as the maximum time which in practice could be allowed. It was evident that for transport a solid, preferably in the form of tablets, would be the most suitable

[1] Epidemiological Society, January 18th, 1901.

form. The following experiments show that sodium bisulphate fulfilled all the requirements:—

Series I.—750 c.c. of tap water infected with one drop of a twenty-four hour broth culture at 37° C. of *B. typhosus* (J. 1).

Agar plate cultures made with 1 c.c. of mixture, and colonies counted after 48 hours incubation at 37° C.	Results obtained after contact of infected water with acid solution for periods of:—			
	5 mins.	15 mins.	45 mins.	24 hrs.
Sodium Bisulphate:—				
1 grm. per pint of infected water ...	B. typh. killed	Sterile	...	...
½ grm. " "	...	Marked reduction	B. typh. killed	...
¼ grm. " "	...	...	No reduction	...
Tartaric Acid:—				
20 grains per pt. of infected water...	...	Sterile	...	...
10 grains do. (A)	Marked reduction	3 colonies	...	...
10 grains do. (B)	...	B. typh. killed	Sterile	...
5 grains do.	...	...	No reduction	1 col.
Citric Acid:—				
20 grains per pt. of infected water...	...	Sterile	...	...
10 grains do.	Slight reduction	30 cols.	...	...
5 grains do.	...	...	...	No reduction
Nitro-hydrochloric Acid, B. P. dilute:				
20 minims per pt. of infected water*	...	Sterile	...	...
5 minims do.	...	...	...	No reduction
Sulphuric Acid, B. P. dilute:—				
20 minims per pt. of infected water	...	reduction	B. typh. killed	...
5 minims do.	...	...	...	No reduction

* The acidity of this solution is equal to 4·8 c.c. $N/_1$ Na OH per litre and the corresponding H_2SO_4 solution 5·8.

Subsequent experiments show the superiority of sodium bisulphate over tartaric acid.

Series II.—800 c.c. of boiled tap water infected with two drops of a twenty-four hour broth culture of *B. typhosus* at 37° C.

Agar plate cultures made with 0·2 c.c. of the mixture.	Results obtained after contact of infected water with acid solution for periods of:—	
	5 mins.	15 mins.
Sodium Bisulphate:— 1 gramme per pt. of infected water ...	6 cols.	B. typh. killed
Tartaric Acid:— 1 gramme per pt. of infected water ...	120 cols.	50 cols.

Series III.—100 c.c. of boiled tap water infected with 1 c.c. (approximately 20 drops) of a twenty-four hour broth culture of *B. typhosus* at 37° C.

Sub-cultures made into broth tubes (incubated for forty-eight hours) by three platinum wire loopfuls, after contact of infected water with acid solution for periods of—

	7½ mins.	15 mins.	30 mins.	45 mins.	60 mins.	2 hours.
Sodium Bisulphate:—						
1 grm. per pt. of infected water ...	+	+	+	—	—	—
0·75 grm. do. do.	...	...	+	+	+*	—
0·5 grm. do. do.	...	...	...	+	+	+
Tartaric Acid:—						
1 grm. per pt. of infected water ...	+	+	+	+	—	—
0.75 grm. do. do.	...	...	+	+	+	—
0·5 grm. do. do.	...	...	...	+	+	+
Sulphuric Acid, dilute B P.:—						
20 minims per pt. of infected water	+	+	+	+	—	—
15 minims do. do.	...	...	+	+	+	—
10 minims do. do.	...	...	...	+	+	+

* Growth after forty-eight hours somewhat inhibited in the sub-culture.

From this series we gather that when a water is heavily infected by a culture of *B. typhosus*, sodium bisulphate (one gramme per pint of infected water) is then only effective if contact has been made for forty-five minutes. Tartaric and sulphuric acids in similar strengths did not so quickly prevent the subsequent growth of the bacillus.

In the case of tartaric, citric, and nitro-hydrochloric acids, it does not appear that anything less than the maximum B.P. dose per pint of water is efficient to sterilize, if the contact is not to last longer than 15 minutes. Half the maximum dose (10 grains) per pint is inefficient in the case of citric and tartaric acids after 15 minutes contact, whilst the minimum dose (5 grains) per pint of citric acid has no effect after 24 hours contact; and in the case of tartaric acid the minimum dose did not completely sterilize after the same period. Of the two, tartaric acid appears to be the most potent in its destructive action upon *B. typhosus*.

The pint has been taken as a standard, as this is the quantity of water which a man might be expected to drink off at once: one gramme to the pint is equivalent to 1 in 568.

Nitro-hydrochloric appears to be more efficient than sulphuric; but no further experiments were made with these, as it was considered essential that the substance to be carried by individual soldiers in the field should be a solid, and not a liquid.

Acid sodium sulphate is not a B.P. medicinal substance. It probably has no purgative effect, as the astringent properties of its free sulphuric acid would tend to counteract any laxative action of the sodium sulphate. The minimum purgative dose of sodium sulphate is a quarter of an ounce, and in the use of 15 grains per pint of water, a man would have to drink seven pints before a quarter of an ounce of a salt, not known to be purgative, would be taken. Even if this quantity of water was drunk in a day, there is no evidence that a quarter of an ounce of the bisulphate would exert any harmful effect.

Series I. shows that the *B. typhosus* is killed by only five minutes' contact with solution bisulphate in the proportion of one gramme per pint of infected water; but fifteen minutes gives additional security.

As regards acidity, the same amount of acid, as measured by decinormal soda solution, appears to be required to produce a similar result in nitro-hydrochloric acid (dilute B.P.), and sulphuric acid (dilute B.P.), while sodium bisulphate in the proportion of one gramme to the pint contains about two and a half times the acidity of 20 minims of sulphuric acid (dilute B.P.). If anything, the nitro-hydrochloric acid appears to be the most efficient *quâ* acidity; and this is intelligible when it is recollected that there is likely to be a small quantity of free chlorine in this acid. The citric and tartaric acids, to be efficient, must contain at least three times the amount of acid, as measured by decinormal soda solution, that is sufficient for nitro-hydrochloric and sulphuric acids.

Series IV.—500 c.c. of boiled tap water infected with one drop of a twenty-four hour broth culture of *B. typhosus*. Cultures from four different sources were used, marked respectively J 1, R, B, and M, thus making four infected waters. The one marked J 1 was found to contain 9,120 colonies of *B. typhosus* per 1 c.c.

Agar plate cultures made with 1 c.c. of the mixtures.	Results obtained after contact of infected water with acid solution for periods of: 3 mins.	7 mins.	10 mins.	15 mins.	30 mins.
	Colonies per c.c.				
Sodium Bisulphate:— 1 grm. per pt. of infected water, J 1	Numerous, but greatly reduced*	50	3	0	0
Do. R.	Very numerous	200	24	0	0
Do. B.	Numerous	140	14	0	0
Do. M.	Very numerous	200	Plate spoilt	0	0

* Greatly reduced when compared with the blank (control experiment).

This series is especially interesting, as it shows that different breeds of the typhoid organism are practically identical in their behaviour.

A further experiment was tried with three waters containing a very large number of organisms, and it was found that sodium bi-sulphate, in the proportion of one gramme per pint, is effective after 15 minutes contact, even for waters containing as many as 52,000 colonies of *B. typhosus* per c.c., and it is extremely unlikely that any drinking waters would be infected with bacilli exceeding in numbers per c.c. this quantity, unless a large quantity of turbid urine from a convalescent case had recently mixed with the water.

Major Macpherson has since pointed out that some of the tablets of sodium bisulphate examined by him were liable to crumble into powder, and that sodium bisulphate is somewhat deliquescent. These two opposite properties are due to mechanical difficulties of manufacture, as I have found that there are varying grades of commercial sodium bisulphate having different physical properties, and quite recently I have pointed out to Messrs. Jeyes & Co. the conditions under which a reliable tablet can be obtained.

Dr. Warner[1] finds that with strong pollutions, although the number of typhoid organisms is very considerably diminished after 15 minutes, a longer time is necessary for sterilization, but adds, "a contact of 30 minutes does undoubtedly, in the majority of instances, destroy *B. typhosus* in a tap water under the conditions of the experiment." This author has further pointed out that *B. enteritidis* is also

[1] *Public Health*, July, 1901.

killed by the re-agent, and has a resistance very much of the same degree as *B. typhosus*, and that *Sp. choleræ* succumbs far more easily than either of these two organisms, and, therefore, is of the opinion that the salt would effect disinfection of contaminated wells more thoroughly than the permanganate at present in common use in India for the purpose.

Prof. Firth has also made a great number of experiments at Netley, to determine the action of bisulphate on the typhoid bacillus, and has shown that by increasing the dose to 3 grammes per pint, the sterilization can be obtained in five minutes; and that if the excess of acidity is then objected to, it is easy to neutralize the water by the addition of 2 grammes of bicarbonate of soda. I am glad to find that this authority is able to say in *Le Caducée* (November 23rd, 1901) that "Cette méthode paraît éminemment pratique pour les besoins du service en campagne;" and further, that "par un emploi judicieux, le bisulfate de soude peut contribuer pour une large part à diminuer les causes d'infection de nature typhique ou cholérique portés par l'eau de boisson."

The bisulphate tablets were used by the New Zealand contingent in the South African Campaign and by Major-General Baden Powell for the mounted police since.[1] Dr. Galli Valerio[2] has confirmed these experiments and has shown that this salt is also destructive of the larva of *Strongylus rufescens*, and suggests its use for other water parasites, *e.g.*, *Uncinaria duodenalis*.

Preservation of Timber. A preservative liquid is made to enter the lower end of the wood, so as to follow the natural flow of the sap and replace it, at the same time combining with putrescible substances, destroying organisms that may be present, and rendering the material unsuitable for the entry of fresh ones. The solution may be either (1) forced in from below by hydraulic pressure, (2) made to enter gradually by a head of liquid, (3) drawn in by encasing the the top with india-rubber or leather and establishing a vacuum while the lower end dips in the antiseptic liquor, (4) the logs may be enclosed in a strong cylinder, which is exhausted and filled with liquid several times. The first method is the quickest, but the second is said to give the

[1] *Public Health*, 1901, p. 369. [2] *Bull. Soc. Vaud.*, 1902, p. 53.

most uniform penetration. The efficiency of the penetration should be tested at various points of the exterior and ends. If the operation has been properly conducted the timber is proof against insects and against the mycelium of disintegrating fungi such as *Merulius lachrymans* (Dry Rot). Where wood has been already attacked by this fungus, care must be taken not to spread the spores, and the best remedy is to spray the parts thoroughly with a hot 1 in 250 solution of mercuric chloride.[1] On the large scale the use of this salt for injecting timber is precluded by its cost and poisonous nature.

Copper Sulphate (Kyanizing) was the earliest agent used, and is still found effectual, although the corrosion by galvanic action of any iron nails, screws, or bolts embedded in the wood is a serious disadvantage. *Zinc Chloride* has been employed on the Continent in Pfister's process.[2] The sleepers on the Hungarian State Railways were treated with this re-agent forced in by steam pressure, but the distribution was found to be somewhat irregular.[3] Acetates of aluminium and lead with glycerine, and sulphites, are examples of the numerous almost useless recipes.[4]

Creosote Oils are now commonly employed. Well-seasoned timber is placed in a vessel so constructed that a more or less perfect vacuum can be obtained by an air-pump. The creosote oil, previously heated from 35° to 50° C., is allowed to enter the exhausted receiver, and pressure is then applied by pumps in order to effect the better penetration of the antiseptic fluid. In S. B. Boulton's improved process, the exhaustion is continued after the entrance of the creosote, which is heated to a temperature somewhat above 100° C. By this method the moisture contained in the pores of the wood is volatilized and removed by the pump, and the oil subsequently penetrates the wood very thoroughly. A great advantage of this process is that wet timber can be at once treated without being previously seasoned. The amount of creosote oil taken up by the timber varies considerably, but is usually about 1 gallon per cubic foot of wood. The smell of creosote oil is much disliked by the lower animals (white ants, etc.), while certain of the constituents have a powerful

[1] See *Public Health Eng.*, November 2nd, 1901.
[2] *Dingler's Polyt. Journ.*, cclxxviii., 221. [3] *Ibid*, cclxxi., 230.
[4] Patents 17,814, 1887; 3356, 1893; 14,599, 1894.

antiseptic action. S. B. Boulton and Coisne, on behalf of the Belgian Government, have proved that in the course of a few years the tar-acids (phenoloids) in railway sleepers, may completely disappear by dissolving and by volatilization, whereas the semi-solid constituents, such as naphthalene, and the higher boiling oils (above 315° C.) remained, and could preserve the wood for sixteen to thirty-two years.[1] Hence the phenoloid bodies of high boiling point and slight solubility are probably of more value for creosoting timber than carbolic or cresylic acids themselves. But the lower phenols are doubtless of value in coagulating the organic matter present in the sap, and should be present in creosote oils in sufficient quantity to effect this.

A disadvantage of this method of preservation is the inflammability of the resulting material and the dense and acrid smoke produced in its burning, hence creosoted sleepers should never be laid in railway tunnels.

Moulds.—The action of chemical agents on moulds and bacteria is in many cases different in degree, and many of the common moulds are highly resistant, although only a few, such as those of ringworm, favus and thrush, are directly connected with disease. We have made several references to *Penicillium*. A. Lode[2] investigated four species of *Aspergillus*. Mercuric chloride proved an effective antiseptic in about $\frac{1}{4}$ per cent. solution: 1 in 1000 required 1 hour to destroy the spores of *A. fumigatus* and *niger*, $\frac{1}{4}$ hour for *A. flavescens*, and $\frac{1}{6}$ hour for *A. clavatus*. Silver nitrate was as good as mercuric chloride in 1 per cent. solution and superior to it in 0·1 per cent. Zinc sulphate or chloride, and copper sulphate 1 per cent., did not destroy the spores in 6 days, nor did 50 per cent. common salt, 30 per cent. calcium chloride, or cold saturated sodium sulphate. 20 per cent. sodium carbonate killed the spores of *A. niger* in 15, and the others in 5 minutes; 10 and 15 per cent. solutions were without action even after 3 days. One per cent. milk of lime had no effect after 6 to 12 days; 10 per cent. in 10 days did not kill spores of *A. fumigatus* and *niger*. 3·4 per cent. chloride of lime (0·67 per cent. active Cl) was nearly

[1] Allen's *Commercial Org. Analysis*, 1886, vol. xi., p. 552; S. B. Boulton, *Proc. Inst. Civ. Engineers*, May, 1884.

[2] *Chem. Centr.*, i., [19], 1122; from *Archiv. f. Hyg.*, xlii., 107.

equal to 1 per cent. mercuric chloride, and even 0·34 per cent. killed all the spores except *A. niger* in 10 minutes. One per mille iodine in KI killed the spores in ½-hour except those of *niger,* which were not killed in 1 hour. One per cent. iodine trichloride was effective in ½-minute, 1 per 1,000 in 10 to 15 minutes. Bromine was effective in 1 and 2 per cent. solution, but 6 per cent. permanganate only gave good results with *flavescens* and *clavatus*. In 5 per cent. phenol none of the spores were capable of development after 1 minute; 2 per cent. lysol destroyed them in 5 minutes, while a mixture of the three cresols had no effect in 24 hours. 2½ per cent. creolin, 1 per cent. saprol, 1 in 2,000 thymol, and 10 per cent. acetone had no particular destructive action on spores.[1] 96 per cent. alcohol was equal to 0·5 per cent. mercuric chloride, while 80 and 60 per cent. were superior to 1 per 1,000 of that salt. Formaldehyde gas had only a slow action (after 1 to 2 hours); 1 per cent. methyl violet had none. Dry heat at 125° C. killed all the spores in 15 minutes, but at 80° C. did not affect them in 7 hours. A current of steam at 100° C. was fatal at once; even water at 80° C. was very effective. In practice, this author recommends current steam, 1 in 500 mercuric chloride, 5 per cent. phenol, 2 per cent. lysol, or 3 per cent. chloride of lime.

[1] The statements as to tricresol, creolin and saprol require confirmation.

CHAPTER XIII.

PERSONAL AND INTERNAL DISINFECTION.

PERSONAL DISINFECTION: Sachets and Lockets practically useless—Cleansing the Hands—Soloids—Gloves—Caustics—Burns and Scalds. DISINFECTION OF CAVITIES OF THE BODY: (*a*) By Washing out—(*b*) By Spray—(*c*) Gargles—(*d*) Injections of Gases or Vapours—(*e*) Inhalations. ANTISEPTIC DRESSINGS: Sulphocarbolate of Zinc—Sozal—Gauzes and Wools—Antiseptic Paper—Rinsing Surgical Instruments. HYPODERMIC INJECTIONS. ANTISEPTIC SOAPS: Mouth Washes—Ointments. "Sanitary Wool" Clothing. INTERNAL DISINFECTION: Charcoal—Chlorinated Soda—Sulphides. INTERNAL ANTISEPSIS: Phenol—Creosote—Essential Oils—Mineral Waters—Acids—Sulphuric Lemonade—The Vienna Mixture—Betol, &c.—Quinine—Benzosol—Phenosalyl. VACCINATION.

PERSONAL DISINFECTION.

THE "last line of defence" includes the precautions taken by the private individual. These may be considered to include cleanliness of the home, cleanliness of the person, and purification of the clothing. The first and third have been discussed, and it has already been pointed out that individual immunity cannot be ensured by carrying about the person camphor, aromatic vinegar, eucalyptus, or other chemical substances which in former times found favour as charms, since these agents cannot reach an effective proportion in the atmosphere. Many devices of little value have, however, been patented for personal protection in even recent years, such as an ingenious arrangement like a vesta-box,[1] with a sliding perforated case, to be kept in the pocket: a mixture of bran, camphor, eucalyptus oil and hydronaphthol, carried in a linen sac, has been seriously recommended to ensure wearers against infection in houses.

In fever cases it is now generally customary to sterilize the hands by washing in a 1 per mille solution of mercuric chloride with a little salt and hydrochloric acid (p. 186), and rinsing them with plain water before washing with soap. In cases of very great danger the clothes are afterwards disinfected by steam. Although many other antiseptics have been proposed for the hands, mercuric chloride seems still to be one of the best; it should not be diluted beyond 1 in

[1] Patent No. 2,770, 1894.

1,000. The same solution should also be used by nurses and attendants when leaving the room; a convenient way of preparing it is to dissolve one "soloid" in a pint of water, taking care to stir well till all has dissolved. Infectious matter is particularly liable to remain under the nails.

The disinfection of the hands and instruments in surgery has recently been the subject of numerous investigations. Reinecke and others prefer alcohol, which however is hurtful to the hands. Dr. R. E. Weir[1] pronounces chlorine to be less injurious and equally efficient. He places "a large pinch" of bleaching powder in the palm of the hand, then a crystal of washing soda "about 1 inch wide," and a little water, rubs the resulting cream (sodium hypochlorite and calcium carbonate) for 3 to 5 minutes over the hands and arms, and washes off in sterile water.

Prof. Mukulicz finds from a series of tests that it is impossible to render the hands perfectly aseptic. He first disinfects his hands as far as possible with alcohol and mercuric chloride, and then draws on a pair of cotton or linen gloves previously sterilized by boiling.

Regarding the value of alcohol as a disinfectant for the hands, Salzwedel and Elsner[2] maintain that alcohol is of use in preparing the hands for operations, not merely because of its hardening effect on the epidermis, but also as an active antiseptic; they consider it intermediate between carbolic acid and corrosive sublimate. The hands, after washing with soap and water, should be well soaked in 80 per cent. acidulated spirit before operating. A new and simple method of sterilizing catgut is described by Dr. C. A. Elsberg.[3] The fatty matter is removed from the catgut by immersing it in a mixture of chloroform one part, ether two parts, for a day. When dry it is tightly wound in single layers on spools for sterilizing. These are boiled for ten or twenty minutes in a hot saturated solution of ammonium sulphate; and the salt which crystallizes upon them on removal is washed off by a moment's immersion and agitation in sterilized water, carbolic acid, or bichloride solution. The catgut is then ready for use or for preservation in strong alcohol. The catgut, prepared in this way, does

[1] *New York Medical Record*, April 3rd, 1897, p. 469.
[2] *Berlin Clin. Woch.*, 1900, June 4.
[3] *New York Med. Rec.*, 1900, p. 760.

not swell up, and remains of the same thickness as the raw material. It is readily absorbed in the tissues of the body, and its absorption takes place between the fourth and eighth days. Bacteriological experiments have shown conclusively that catgut prepared by this method is always sterile after five minutes' boiling.

C. B. Lockwood has made a long series of experiments on sterilization in surgery. Sponges can in most cases be sterilized by sulphurous acid, but "when used for septic cases it is better that they should be burnt." Towels were steamed for 40 minutes and then immersed in 1 in 40 phenol; out of 40 trials 38 were sterile, 1 developed B. subtilis, and 1 an unknown bacillus. Silk boiled 20 minutes and immersed in 1 in 60 phenol was invariably sterile. Silkworm gut and catgut presented exceptional difficulty. He treats them by winding on a board and scrubbing with soap and water, drying and removing grease by soaking for 6-24 hours in ether, then leaving in mercuric iodide solution, 1 in 250, for 72 hours; or they may be kept in this liquid without injury (compare p. 319). As to the hands, the nails being cut as close as possible, not less than 3 minutes scrubbing with hot water and soap, and 2 minutes immersion in HgI_2 dissolved in methylated spirit, using clean and sterilized hand basins, gave in 38 out of 39 cases an aseptic result.

The skin of the patient is shaved, soaped, and scrubbed, and the fat is removed by ether or turpentine. A 1 in 500 solution of HgI_2 in methylated spirit is next applied. The disinfection is particularly difficult when the part is covered with hair.[1]

Cuts or abrasions when handling septic matter frequently cause blood-poisoning and even specific disease. Waterproof gloves are manufactured, but as they very much deaden the delicacy of touch, they are seldom used. If a cut or wound has been accidentally produced, cauterizing with nitrate of silver, nitric acid, phenol, permanganate, or osmic acid is frequently recommended, but the scar left is often very painful and troublesome to heal, besides not being thoroughly safe against inoculation. Covering with lead or court plaster, or with collodion; painting with iodine;

[1] See *Brit. Med. Jour.*, October 25th, 1890; May 28th, 1892; January 27th, 1894; July 11th, 1896; September 17th, 1898.

thoroughly drying the cut and painting with a solution of Stockholm tar or Burgundy pitch in alcohol, ether, or acetone, are among the other treatments suggested. None of these give absolute immunity, so that, in case of accidental puncture during a *post-mortem* or operation, or in handling contagious matter such as dead meat, skins, or evacuations, it is probably safest to wash immediately with mercuric chloride, dry and at once cauterize, and thus combine the two precautionary measures. When, unfortunately, the abrasion has not been noticed at the time, this treatment should still be resorted to. Afterwards, hypodermic injections of an antiseptic have been recommended, and cinnamic acid, styrol, phenyl-propionic acid, β-naphthol, and betol are used for this purpose; phenol, or any other re-agent which coagulates the blood, is of course inapplicable. For ordinary bites and scratches similar treatment may be adopted; the part should be afterwards protected by antiseptic gauze or wadding. Burns and scalds are liable to septic poisoning if the epidermis is broken, so that they also should be protected, but not cauterized. Wasp-stings and insect-bites have caused death. The best remedies are liquor plumbi subacetatis (p. 178) or Goulard's extract, and the old-fashioned hartshorn and oil.

Disinfection of Cavities of the Body.—Several methods in use have been alluded to in the chemical section. The following is a summary of processes:—

(*a*) *Washing out* by inflow and outflow tubes with lukewarm water, then with a weak solution of an antiseptic, which should not be one with a strongly poisonous action on the system. Phenol, resorcinol, and mercuric chloride have been absorbed with dangerous, and even fatal, effects. Iodine is very irritant. Iodol has been recommended, likewise betol and phenyl-propionic acid.[1] Salicylic acid is dangerous, irritant, and not effective. A solution of silver nitrate in distilled water has been tried with great success: the objection to it is that if weak (1 in 1,000) it is almost wholly precipitated by the chloride of sodium in the fluids of the body, and if stronger (1 in 200) it has on some occasions caused sloughing. Silver preparations free from these faults have been described, p. 193. Sulphocarbolate

[1] Klein, in Stevenson and Murphy's *Hygiene*, p. 261.

of zinc, 1 in 1,000, has the advantage of being mildly astringent, and seems to be safe; a sulphocresylate would probably be still safer, and is a stronger antiseptic. Alumnol (p. 388) is a useful and powerful astringent. Glycerine is irritant to mucous membranes, but it is useful when it is necessary to keep surfaces moist. On boric solutions see p. 140. A number of the newer antiseptics are advocated for this special branch of antisepsis, but they await more extended and impartial surgical trials, as many of the earlier statements have not been verified by recent experiments.

(*b*) *Spraying*.—Any of the former may be used in the form of spray, the advantages being that stronger solutions may be used, that only the affected parts are treated, that the irritating and depressant action of large volumes of water are avoided, that a local refrigerant effect may with safety be produced, that much less of the medicament is required, and that the action can be watched, and the process repeated with facility and without shock. The various spray-producers nearly all act on the same principle; a current of air is blown by an india-rubber ball, with a second ball to render the blast steady, across the narrowed orifice of a vertical tube dipping into the liquid in the bottle. The strength and fineness of the spray are regulated by the relative size and position of the orifices, and the amount of liquid delivered is known by the graduations on the bottle. Chlorine water, with or without cocaine hydrochloride, has been employed, and boric sprays are frequently used for the throat. Solutions in ether were recommended by Philip Sterne, as far back as 1867,[1] as antiseptic spray. As sprays are said to more easily penetrate parts covered with hair, mercuric chloride, chrysarobin, resorcinol, and formaldehyde have all their special uses.[2]

(*c*) *Gargles* of honey and borax, tannin, and alum have been used from time immemorial. This method is easily used by unskilled persons, but it is inferior to that of spray, as there is no certainty that the parts affected will be reached. It is evident that no drug which will be poisonous if swallowed can be employed.

[1] *Advice to the Consumptive.*

[2] *Pharm. Journ.*, vol. xxi., p. 1040.

(*d*) *Injections of Gases or Vapours.*—It is a familiar fact that if an abdominal cavity be wounded, septic poisoning and peritonitis is almost certain to supervene, and that washing out may be dangerous, owing to the intense irritation, and may even cause the above disastrous result. In these cases spraying is also interdicted. Life has frequently been saved by gaseous injections, and sulphur dioxide seems to be the best remedy to employ. This can be obtained by blowing a current of air through a tube containing some fragments of sulphur, and allowing the gas produced to enter the cavity. The part of the tube containing the sulphur is heated by a spirit lamp, taking care that the end of the tube is kept cool. Blowing air through a saturated solution of sulphurous acid or through a mixture of a sulphite with acid is inferior to the above, as the quantity delivered is uncertain. Liquefied sulphurous acid from a Boakes' bottle cannot be used for this purpose, as the cold produced is intense and would produce shock. Unfortunately sulphurous acid, by being absorbed into the system, is recorded to have produced fatal effects in one or two cases. Baxter experimented specially on its effect on the virus of peritonitis[1] with favourable results. Chlorine, bromine, and iodine vapours are irritant and dangerous. Many others, such as chloroform, ether, phenol, etc., are excluded by their narcotic action. Iodoform vapour has caused poisonous effects. Carbonic acid is very soothing, and rapidly subdues inflammation, but for this purpose the gas must be thoroughly washed. It is only a feeble antiseptic, but would be a better medium for other antiseptics, such as eucalyptol, than air.

(*e*) *Inhalations.*—Chloride of ammonium is beneficial in bronchitis and asthma. The simple breathing of the vapour of vinegar and hot water also gives relief. Koch proved that a number of essential oils when inhaled with steam are inhibitory to tubercle.[2]

Antiseptic Dressings usually include cotton-wool, wood-wool, or gauze, which act as germ excluders; they are kept moist with diluted soda chlorinata (p. 85), or with boric acid solution (p. 140); sometimes phenol 2½ per cent., or mercuric chloride 1 in 1,000, are used, but they are liable to

[1] *Appendix to the Report of Med. Off. of the Privy Council*, 1875.

[2] Marshall Ward, *Journ. Soc. Chem. Ind.*, 1893, p. 943.

produce ill effects on absorption. There is a great advantage in changing the agent every few days; even the most innocuous are liable to become irritating if continuously used. An alcoholic solution of coal tar has been much used for many years under the name of Wright's Liquor Carbonis Detergens. Diluted cresol and Sanitas fluid are useful in rotation with boric and with chlorinated lotions. Glycerine is objectionable. Zinc sulphocarbolate and sozal (the aluminium salt) are used as astringent and antiseptic lotions (p. 212). Diaphtherin (p. 257) in 1 per cent. solution has been much used in Germany. Tichborne recommends[1] zinc sulphite as non-poisonous and not irritating.

Gauzes and Wools are described under iodoform, boric, and salicylic acids, and zinc-mercuric cyanide (p. 189). Hydronaphthol gauze (p. 242) has recently been much praised. Salicylic gauze is irritating. Thymol or eucalyptus gauze would seem to be the best and safest. Benzoated gauze, 5 per cent., has also been recommended.

M. Duquaire, of Lyons, has invented an ingenious antiseptic paper. The material is asbestos with about 5 per cent. of ordinary paper pulp, worked into soft paper and soaked in a petroleum-benzene solution of beeswax. The solvent having been evaporated off in the open air, the tissue is ready for use. When required it is set on fire, and is so made aseptic, and may be employed at once for dressing wounds.[2]

Unfortunately many of the antiseptic wools and dressings met with commercially are of uncertain composition, and insufficient attention has hitherto been paid to the importance of storing these articles in such a way that the antiseptic present shall not be volatilized.

In France their sale, except by duly qualified pharmacists, is forbidden, but the question does not seem to have been discussed in England.

Surgical instruments must be rinsed in a disinfectant which does not corrode steel; the various cresol preparations are much used for this purpose. Those that turn turbid with water have the disadvantage that the instruments cannot be so well seen (see p. 230). A good preparation seems to be

[1] *Brit. Med. Journ.*, 1890, p. 1064.

[2] *Chem. and Drug.*, 1890, p. 39.

potassio-mercuric iodide, 1 in 4,000, or two of the soloids to a pint, for hands or instruments.

Antiseptic Hypodermic Injections.—Several of these have been much employed recently in France, particularly for phthisis; the basis is olive oil, and all the ingredients are carefully sterilized by heating to 120° C.

Picot uses guaiacol 5, iodoform 1, olive oil to 100; Morel-Lavallées' solution consists of eucalyptol 12, guaiacol 5, iodoform 4, olive oil to 100.

Also solutions in olive oil of creosote 1 in 15, and eucalyptol 2 to 4 in 10 have been suggested.[1]

A number of mercurial compounds are used specially in syphilitic affections. They have been already enumerated and described (p. 190).

Disinfectant Soaps and Ointments.—In spite of increased knowledge of disinfectants, little attention seems to have been paid by soap manufacturers to this subject, so that soaps which were introduced many years ago still find favour with the public, although their efficacy as germicides is very small. This has arisen partly from the fact that it is seldom that disinfectant soaps are properly tested as to their germicidal action upon specific organisms under conditions which approximate to their use in practice, and partly owing to the fact that there are many disinfectants which have valuable properties as such, but which are totally unfitted for use in conjunction with soaps.

The conditions which obtain when a disinfectant soap is used are very different from those of ordinary disinfecting. As a rule, the time of contact is much shorter, and the volume of water or vehicle much less. As the time of contact is short, so it is necessary that the percentage of active ingredient should be high. As the volume of water used per unit weight of disinfectant soap is usually much less than is recommended when a liquid disinfectant is employed, this will assure a higher percentage strength of the active ingredient if it is present in the soap in anything like reasonable proportions. On the other hand, it is important to note that, unless the disinfectant employed is readily soluble in water, actual contact of the infected parts with the disinfectant cannot be attained in the limited time given to

[1] Vicario, *Amer. Druggist*, June 15, 1891.

washing. In coal-tar soaps and those containing oils which are not very soluble in water, although the disinfectant is emulsified by the soap, the actual laving of every part of the infected area by the active ingredient for the necessary time to effect the death of the micro-organism is by no means certain. Organisms differ very markedly in their resistant power. Many of them form spores which are especially difficult to kill, so that even when a soap contains an approved disinfectant, the latter must be present in quantity above that required for the fatal dose for the most resisting spores.

It is of extreme importance to the soap manufacturer that he should not only carefully select his disinfectant and ascertain its purity and efficiency, but should also devote especial care in admixing this ingredient in the right proportion, the exact amount of the medicament being stated on the wrapper of each piece.

The disinfectant power of warm 2 per cent. soda solutions is considerable, even without the presence of any fatty acids, and they can be used with advantage for scrubbing floors, mantelpieces and furniture. At 60° C. a contact of 5 minutes ensures the death of most organisms.[1]

The stock or basis of a medical soap or ointment is by no means unimportant. It is necessary that the medium in itself should produce no disturbing action, therefore in many of the best known brands great care is devoted to the attainment of chemical neutrality, *i.e.*, that the fatty acids and alkali should be combined in molecular proportions, since free fatty acids are said to induce inflammation, while any large excess of alkali is known to be irritant. Raw materials are carefully selected as neutral, uncoloured, and almost inodorous glycerides. It is probable, however, that such expensive precautions have been too far insisted on, as even a chemically neutral compound of a fatty acid with an alkali is decomposed in contact with water, a portion of the potash or soda being set free. F. Krafft and A. Stern (*Ber.*, xxvii. 1747), in confirmation of Chevreul's early work, have found that soap in a large quantity of hot water gives a precipitate of the sodium salts of palmitic and stearic acids, while sodium oleate, not being so readily decomposed, remains in solution along with free alkali. An olein basis

[1] Simon, *Zeitsch. f. Hyg.*, 1903, p. 349; also *Kurpjuweit, loc cit.*, p. 369.

would therefore seem preferable to the employment of a harder fat. At the same time, since for disinfectant soaps the chief condition is that the agent should be rapidly disengaged *in sufficient quantity* in contact with the surfaces, a softer and more easily dissolving soap is directly indicated.

The alkali of commercial soap is, of course, soda, but *potash or soft soap* figures in several Pharmacopœias as "Sapo kalinus," "viridis," or "mollis." It is generally made with linseed oil (B.P. olive oil), has a pale brownish-green colour, and is reckoned to be specially beneficial in some skin diseases. It would be useful to determine whether an admixture of a potash-soap with the ordinary soda-soap would produce a basis giving greater activity when used in such proportion as not to give too great softness to the product. E. W. Lucas has already shown (B.P. Conference, 1894) that a mixture of one part potash-soap to five of soda-soap solidifies, and can be advantageously employed as a basis for liniments. The solubility of drugs in a potash-soap does not appear to have been investigated. The chief objection to commercial soft soap is that not having been "salted out" or separated as soda soaps are, it retains, besides a large and very variable amount of water, all the glycerine of the original fat, and in addition the saline impurities of the alkali used, some of which may interfere with the action of the medicaments. To meet this objection, Müller and Graube[1] have prepared a "pure soft soap," which they term "Savonal," by saponifying olive oil in the cold with alcoholic potash (which contains almost exclusively potassium hydroxide, most of the impurities being insoluble), and neutralizing the resulting solution by careful addition of fatty acids obtained from a portion of the alcoholic soap by precipitation with hydrochloric acid. The alcohol is then distilled off in a water bath, when "Savonal" in an unctuous condition is left. It will be noticed that the glycerine is still left in. A really pure soap, if necessary, could be quantitatively prepared by saturating alcoholic potash with the washed fatty acids, also dissolved in alcohol. By testing measured portions, using phenol-phthalein as an indicator, the relative amounts of the two solutions could be obtained. Heat is avoided as much as possible, on account

[1] *Pharm. Zeit.*, 1897, 546. *Nouveaux Remèdes*, xiii., 437.

of the production of odour or colour. A liquid is prepared by adding "a few percentages of glycerine" and enough distilled water to make up the sp. gr. 1·050 to 1·055; this is used as a medium for many drugs. Among the strengths given are: phenol, naphthol, or resorcin, 5 per cent.; salol (page 269), 5 to 10; cresol, 0·25 to 2; chrysarobin, 10; iodine, 1 to 2, with 10 per cent. of potassium iodide.[1]

Many of these antiseptics will not dissolve to a clear liquid in the aqueous soap. If the alcohol were not all distilled off the solubility would be often increased, the product approximating to many of the official Linimenta.

Wunscheim states that phenol, orthocresol, lysol and creolin have less disinfecting power in glycerine soap solutions than in aqueous soap solutions of the same strength.[2]

Unna and others are of opinion that medicaments are more easily absorbed if the soap is "superfatted," or contains an excess of the fatty menstruum; but however preferable for toilet purposes as more emollient to the skin, these soaps seem not to be so suitable as vehicles for many drugs as those containing a moderate excess of alkali. The presence of free oils or fats is distinctly inimical to antiseptic action. Koch was the first to point out that carbolic acid dissolved in olive oil, or "carbolized oil," possessed no antiseptic properties. Lenti (*Union Pharmaceutique*, xxxv., 58) concluded from his observations that fatty substances are unsuitable vehicles for disinfectants, as they impeded the germicidal action of mercuric chloride, phenol, and several other bodies.

J. Bosisto states that an ointment containing simply the volatile oil of eucalyptus is inferior to the fresh leaves as used in Australia.[3] E. Sage[4] says that neither vaseline nor lard is a suitable solvent for a preparation of cocaine, and that the idea of the superiority of such a preparation to one containing the hydrochloride, dissolved in a little water and rubbed up with fat, is fallacious. Dr. Breslauer's experiments with mercuric chloride, boric acid, silver nitrate, etc., admixed with oil, vaseline, lanoline, and other excipients, prove that while the lanoline gave the best results, the

[1] *Year Book Pharm.*, 1900, 209.
[2] *Chem. Centralblatt*, 1901, i., 408.
[3] *Pharm. Journ.* [4], ii., 224.
[4] *Ibid.*, iii., 28.

presence of the free oil or fat in all cases strongly militated against the germicide, various bacilli surviving in oil far longer than in aqueous solutions. It would seem, therefore, that the presence of water was necessary to the antiseptic and even to the full medicinal action of ointments (which would explain the above result with wool-fat or lanoline, containing as it does about 25 per cent. of diffused water), and that it would be preferable to mix in a mortar an aqueous solution of the drug with the fatty basis shortly before being used, as these moist ointments in many cases do not keep well. A. St. Onge[1] gives a table of the proportions of water, alcohol, and glycerine, which he found miscible with various fats.

Dr. Baldas[2] found no pathogenic organisms in crude oils of commerce, but proved that if they were introduced, they could remain in the oil and retain their virulence for two months unless the oil were heated. He remarks that this should lead to great care, with regard to the oils used in medicine and surgery.

Vicario noticed, in 1891, that fixed oils frequently contained germs. From these and other observations it has been recognized that oils and fats used in ointments and soaps must be sterilized by heat; usually this is done in course of manufacture.

It must be remembered that soaps themselves have considerable antiseptic power. The early experiments of Max Jolles[3] have shown that in the case of typhoid bacilli the disinfecting action is more marked at 4° to 8° C. than at ordinary or higher temperatures, therefore that with cold water soaps would be more active than with hot. When rags infected with the germs were treated with a soap-solution the effect was very marked, even a 1 per cent. solution being injurious to the germs in fifteen minutes, and a 6 per cent. solution resulting in their entire destruction. A 3 per cent. solution was fatal in one hour, and in 1 per cent. no germs remained capable of development after two hours' immersion. B. coli communis was less easily destroyed; at low temperatures a 2 per cent. solution was fatal in six hours.

[1] *Zeits. des oesterr. Apoth. Verein,* xxxiv., 712; *Year Book of Pharmacy*, 1897, p. 219.

[2] *Giorn. Real. Soc., Ital. Igiene*, February, 1901.

[3] *Zeits. f. Hygiene*, 1895, 130.

According to Harz and Von Miller, a solution of 1 in 1500 or 1 in 2,000 of soapy water is fatal to all injurious plant parasites.

There is no doubt that prolonged contact with soap renders surfaces practically sterile, but, under common circumstances, ordinary soap fails to be effective.

Reithoffer[1] refers to the different behaviour of various germs to soap solutions. Thus anthrax bacilli are easily killed in weak solutions (?), but typhoid and cholera germs are far more resistant. He notes that in Behring's opinion the disinfectant power of a soap is dependent on its alkalinity. Experimenting with common soft soap, with scented almond soap, and with a patent potash soap, Reithoffer found that they all had a high degree of disinfecting power against typhoid bacilli, B. coli, and the cholera organisms, but their action is very feeble against pus cocci. Staphylococcus pyogenes aureus will remain unchanged for an hour or more in 18 to 20 per cent. soap solution, whilst a 10 per cent. solution of the same soap will kill typhoid bacilli in one minute. Experiments with carbolic and lysol soaps showed that although the power as tested on cocci was slightly higher than the simple soap, yet it was much weaker than was a solution of the disinfectant without the soap. From these observations it may be concluded that in surgical practice the use of a disinfectant soap is inefficient, the better plan being to wash first with soap and afterwards to apply an antiseptic lotion.

Beyer[2] has shown that in the case of hospital clothing with various surgical stains, soaking the garments in solutions of various soaps for one or two days failed in every instance to kill cholera, typhoid, and pyogenic organisms. He attained success with lime-water in from twenty-four to forty-eight hours, but woollen goods were spoiled. In this case, if the soap had been supplemented by a good antiseptic, more favourable results might have been attained.

With reference to medicinal agents used in soaps, acids and free halogens are obviously incompatible, the former being neutralized by the alkali, or precipitating the fatty acid, the latter combining at once with the fat. A hypochlorite of K or Na is compatible to a certain extent, but

[1] *Arch. für Hyg.*, xxvii., H. 4. [2] *Fortschritt de Medicin*, No. 1, 1897.

the disinfectant action is much less than that of free chlorine. The oxygen compounds of bromine and iodine do not seem to have been studied in this respect. A vast number of organic bromo- and iodo- compounds have been introduced; some of them seem to be useful, but most are irritating; the majority have very unpleasant odours.

Fluorides and silico-fluorides are strongly antiseptic and non-poisonous (p. 105), and were patented under the name of "Salufer." They might be used in conjunction with soap, as Thompson states that a solution of sodium silico-fluoride is not irritating, and "is stronger than 1 per 1,000 solution of $HgCl_2$," and it is obviously compatible with soap.

Sulphur.—Sulphur and alkaline sulphides blend well with soap, and have long been known as useful in skin diseases. Sulphur, even in the form of "milk of sulphur," is very slow in its action, on account of its insolubility. The alkaline sulphides are caustic, having been used from Roman times as depilatories; and recently ichthyol and sphagnol have been suggested as convenient means for administering sulphur in soaps. Most of these gradually evolve H_2S, and therefore yield an unpleasant odour, hence are not popular, although this gas is a prominent feature of their antiseptic action.

Boric acid in soaps would be converted into sodium borate, and would have little efficiency. It is added to destroy alkalinity.

Metallic Salts.—These can only be introduced into soap in very small quantities, as nearly all, except the salts of Na and K, are precipitated in an insoluble form, and on washing disappear from the water in the curd, which can have little effect or value.

Various oleates, or solutions of metallic oxides in oleic acid, more or less well defined as compounds, have been introduced into the Pharmacopœias. They mix well with unguents, and are said to be more readily absorbed and less irritating than older remedies. Hence it has been proposed to incorporate them with soaps. But since the efficiency of soap depends upon its solubility in water, the curdy precipitate, as mentioned above, is probably inert; since also most oleates of metals are insoluble in water, the question arose as to how far an oxide or an oleate could be made soluble for use in ordinary washing. As an example, I

dissolved some zinc oleate, B.P., in a minimum quantity of soda; to the hot clear solution I added 10 grammes of yellow soap, and incorporated. When cold, the soap separated from the mother liquor, which was strongly alkaline, and contained practically all the zinc. This process not working, zinc hydrate was prepared and boiled with soda to form a sodium zincate as neutral as possible. Yellow soap was then dissolved in the filtered solution, boiled down, and allowed to set. It formed a soap of good washing qualities, not unduly alkaline. On using with water in the ordinary way, the zinc was found to be in solution, showing that there was no separation of insoluble zinc oleate. It would therefore seem that metallic oxides dissolved in soda or potash might give better results than the oleates.[1]

Arsenical soaps have come under prominent notice of late owing to recent prosecutions, which showed that the amount of arsenic present was almost infinitesimal, and quite insufficient for antiseptic or disinfectant properties, although the small quantity with constant use might have some effect on the skin.

The powerfully antiseptic action of mercury salts suggested their employment in medicated soaps. It was difficult, however, to prevent the production of the insoluble mercuric oleate which has little or no germicidal action and also prevents the formation of a good lather, while any surfaces on which a mercurial preparation is used are liable to become blackened by H_2S, and organic matter is apt to reduce and throw the mercury out of action. One form of mercurial soap contains mercuric chloride, ammonia-mercuric chloride, together with β-naphthol, eucalyptol, and methyl salicylate. The salts are incorporated with a neutral soap in a dry state in the process of milling, and are therefore possibly present unchanged. It is claimed that they are active at the moment of decomposition, as in washing, though afterwards converted into oleate.

The double iodide of K and Hg has even stronger germicidal powers than $HgCl_2$. In certain proportions it is easily incorporated in the soap stock, and I have found that when dissolved in warm water there is no separation of any insoluble mercury compound. The strength recommended

[1] See *Journ. Soc. Chem. Ind.*, 1901, 498.

is 1 to 3 of HgI_2 and 1 to 3 of KI in 100 of soap. It is said to be effective in a proportion of one part of HgI_2 to 4,000 of water. A soap of this kind, which is in the market, I have found by analysis of some samples to have the following composition in the three grades sold :—

Nominal strength.	KI.	HgI_2.	Biniodide. $KHgI_3$.
3 per cent.	2·25	2·39	3·4
1 ,, ...	0·94	0·63	0·9
½ ,, ...	0·45	0·26	0·37

More potassium iodide is therefore present than is sufficient to form the double salt. Potassio-mercuric iodide has the advantage of being compatible with strong alkalies, as is shown in the preparation of the Nessler test; moreover, it does not precipitate albumen, and is not easily reduced. According to Dr. Sims Woodhead,[1] the cheaper "carbolate-of-mercury" soap is not so powerfully disinfectant, and is considerably slower in its action. Obviously mercurial soaps should not be used popularly or indiscriminately. We can conclude that with regard to metallic soaps, as it is known that a metal in the form of oleate is readily absorbed by the skin, if an internal effect is wished for, an oleate soap will succeed; but if a local antiseptic or disinfectant action be required, oleates or other insoluble salts are practically useless, and means must be taken to obtain a mixture, like the mercuric-iodide soap or the zinc soap mentioned above, which yields the metal in a soluble form to water. The latter use of soap is obviously the natural one, the former more properly belonging to an ointment or liniment.

Within the last few years I have investigated bacteriologically the relative antiseptic properties of a number of commercial and medicated soaps. In one series comparison was made with a curd soap containing 32·5 per cent. of water and 60·8 per cent. of fatty anhydrides, using for the experiments a 2 per cent. sterilized solution. Inoculation with active bouillon-cultures gave results which may be summarized in the tables, + indicating growth, and − sterility :—

[1] *Journal Soc. Chem. Industry*, March, 1888

I.—*Bacillus Coli Communis in Vigorous Growth*

Time.	Curd Soap.	A Scented Curd Soap	Carbolic 10%	New Disinfectants. A	New Disinfectants. B	HgI_2 3%	Formalin 0·4%
5 mins ...	...	...	...	...	...	–	+
15 ,, ...	...	...	...	...	...	–	+
25 ,, ...	...	...	...	...	...	–	+
30 ,, ...	+	+	+	+	+	–	–
1 hour ...	+	+	+	+	+	–	–
1½ hours ...	+	+	+	+	+	...	...
2½ ,, ...	+	+	–	+	+	...	...
3½ ,, ...	+	+	–	+	much attenuated	...	...
4 ,, ...	–	–	–	–	–	–	–

II.—*Staphylococcus Pyogenes Aureus*

Time.	Curd Soap.	Scented Curd.	Carbolic 10%	New Disinfectants. A	New Disinfectants. B	HgI_2 3%	Formalin 0·4%
10 mins. ...	+	+	–	+	+	–	+
20 ,, ..	+	+	–	+	attenuated	–	+
30 ,, ...	+	–	–	–	–	–	–
Between 1 and 4 hours	–	–	–	–	–	–	–

The soaps were tried as sold. The relative amounts of disinfectants present in the solutions of the same strength (2 per cent.) would be—

Carbolic 0·2 per cent. or 1 in 500 of phenol.
A 0·06 ,, or 1 in 1666 of disinfectant.
B 0·03 ,, or 1 in 3332 ,,
HgI_2 0·05 ,, or 1 in 2000 of HgI_2.
Formalin 0·008 ,, or 1 in 12,500 of formaldehyde.

It will be seen that in these experiments the formaldehyde was used in unduly small quantity, but the results are good.

Carbolic and Cresylic Soaps.—An ordinarily stated commercial strength of these soaps is 10 per cent., but it is frequently much less. The odour of all forms is very pronounced, and often constitutes an objection. Several varieties are advertised as "of delicate odour" and "not unpleasant in any boudoir," etc.; but, although the homologues of cresol have a higher disinfectant power than

phenol, they will still, if in effective proportion, manifest their distinctive odour, so that a soap of the tar order, however disguised with eucalyptus, gaultheria, or other scents—which in themselves, by the way, have little disinfectant value—cannot be free from a more or less tarry odour. A large number of "toilet" soaps are advertised in conjunction with the names of various disinfectants, and contain such an infinitesimal quantity of the various re-agents as to be quite useless in a germicidal sense; they are, in fact, objectionable, as conveying the feeling of a fallacious immunity.[1] "Carbo-sapol" contains 50 per cent. of Calvert's No. 5 carbolic acid, 25 per cent. yellow soap, and 25 per cent. soft black soap.

Prof. Mikulicz, of Breslau, uses a spirit soft soap for disinfection of the hands. This owes its efficacy mainly to the alcohol, as the alkalinity of the soft soap in solution is not high. A liquid ethereal antiseptic soap for this purpose is now manufactured in America and is also employed as a parasitic dressing.

Essential Oils.—The disinfectant power of the essential oils has been much over-rated, and to be at all effective they require to be used in such quantities as are liable to cause serious irritation to the skin, many of them having a blistering action as powerful as turpentine or mustard. When desired as perfumes the amount added should be minute, an over-strength having caused many soaps, otherwise well manufactured, to lose favour. When such ingredients are added to the crutching-pan, it is always desirable to neutralize the free alkali at this stage by the ammonium-salt process, or to postpone the addition of the oils until after the operation of fitting. Such has been the reaction against perfumes that prominent brands are advertised as "unscented," and others as "delicately scented."

Volatile disinfectants, such as phenol, camphor, thymol, etc., suffer considerable loss if introduced in crutching in the ordinary manner or added during re-melting, so that the quantity present becomes uncertain; it seems, in fact, desirable that all such medicinal soaps should be milled or plotted, as the machines are very convenient for regulating the amount of disinfectant added.

[1] The percentage of phenoloids should always be stated on the packages of these soaps. For processes of estimation see pp. 475, 476.

The cakes should evidently be packed in tinfoil (except in the case of mercury soaps, when oiled paper or thin gutta-percha should be used), and should be kept in a cool place. It has been proposed to coat the surface of the tablet with a film of gelatine or wax.

In a series of comparative experiments made in 1896, using 2 per cent. solutions and broth-cultures at 37° C. of two representative organisms with the usual precautions, I found that oil of cloves when present in a soap had little antiseptic action.

Organism.	Time required to kill the Organism.					
	Curd Soap.	Carbolic Soap, 3 lb. per cwt.	Clove-oil Soap, 3 lb. per cwt.	Clove-oil Soap, 7·5lb per cwt.	Biniodide Soap, 0·5%	Biniodide Soap, 1·0%
B. coli communis ...	between 2 and 4 hours	between 2 and 4 hours.	alive after 6 hours.	between 2 and 4 hours.	less than 15 mins.	less than 15 mins.
S. pyogenes aureus	Organism alive after 6 hours.				between 15 and 20 minutes.	under 15 minutes.

The carbolic and two clove-oil soaps have therefore an antiseptic action equal to, but not exceeding, ordinary curd soap. In the case of S. pyogenes aureus, the limit of time required to produce disinfection was not reached, but as both the strength and the time much exceeded those which obtain in practice, it was not considered necessary to prolong the experiments. The time had also much exceeded that required by the biniodide.

A comparison of the amount of antiseptic present in the case of the carbolic and mercurial soaps would point to the *à priori* probability of the above results, since—

The 2 per cent. solution of carbolic soap contained 0·052 per cent. phenol.

The 2 per cent. solution of mercurial soaps contained 0·01 and 0·02 per cent. of mercuric iodide respectively.

Solutions of 1 in 10,000 and 1 in 5,000 of mercuric iodide are known to possess decided antiseptic properties, but a solution of 1 in 2,000 of carbolic acid is practically useless.

Another series of experiments with B. coli communis and 2 per cent. solutions gave :—

Curd soap	Sterile between 1 and 3 hours.
Zinc hydrate soap, *ante*, p. 399	Alive after 3 hours.
Carbolic soap	Sterile between ¼ and 1 hour.
Coal-tar soap	,, ,, ,, ,,
Sanitas soap	Alive after 3 hours.
Terebene soap	,, ,, ,, ,,

The variation in these results is influenced by the amount of water present. Thus, taking a dry curd soap, such as was used in the above experiments, in proportion corresponding to soaps containing 33 per cent. and 66 per cent. of water, the following results were obtained :—

	3% dry soap	3% of soap containing 33% of water.	3% of soap containing 66% of water.
Time required to kill B. coli communis...	Attenuated after 1 hour.	Less than 3 hours	3 hours

Mouth washes and Tooth powders.—These are too numerous to be discussed here. They are chiefly empirical mixtures which owe their reputation to custom or advertisement. Some people use only water with a little soap in it to clean the teeth, but it is of advantage to assist the friction with a powder, and also to use an antiseptic which will penetrate the crevices which cannot be reached by the brush. Wood-charcoal powder is excellent, but rather disagreeable. The best is said to be Areca nut; it should not be used constantly, as it is apt to scratch and wear away the enamel. Prepared chalk is the best foundation for tooth powders, as it neutralizes any acid, and being softer than the enamel, it polishes but does not scratch. Powdered myrrh, Peruvian bark, quinine, and other ingredients are frequently added. Honey, borax, various scents, such as orris and rose, are among other substances which are commonly found in dentifrices. As a mouth wash, where there is decay and the breath is offensive, one of the best applications is chlorinated soda diluted to about 1 per cent., and used occasionally. It is not very pleasant, but it removes all odour. Saccharin, sodium bicarbonate, oil of peppermint, benzoic and boric acids, tannin, tincture of iodine (dangerous), and tincture of myrrh are also occasionally met with.

Ointments.—With the exception of vaseline, which in itself is decidedly somewhat disinfectant, and to a certain extent the preparations of glycerine such as "glycerinum

saponatum," described at p. 328, the bases of ointments are only antiseptic in the sense that they exclude air and moulds and bacteria from the surface covered. Otherwise their virtues are simply emollient, or depend on the drug, such as mercury or zinc, which is incorporated with them.

Sulpholeate of sodium has been suggested for dissolving antiseptic drugs and yielding them to the skin.[1]

Lanoline and cold cream contain water and thus differ from other ointment bases. If therefore, antiseptics are incorporated with them they dissolve in the water and so come in contact with the surface of the wound and kill the organisms present. When oil, vaseline, etc., are used, as they contain no water, the antiseptic remains in the ointment and only a fraction reaches the surface of the patient, hence the uselessness of carbolized oil as shown by Koch and Breslauer. The property of formaldehyde to form condensation products with fat and oils has led to its use for the preparation of antiseptic oils. *Lanoform,* for example, is wool fat heated with formaldehyde.

Internal Disinfection.—In the alimentary canal, and sometimes in other parts of the body, there are always present large numbers of micro-organisms, and it is probable that the process of digestion itself may be assisted by certain microbes. Even pathogenic bacilli may enter in limited numbers without producing disease. They are not destroyed by the gastric juice, but rarely survive in the struggle for existence with the far more numerous non-disease-producing organisms. If they are present largely in food, water, or air, it is impossible to exclude them from the body, and difficult to kill them when they have entered.

The removal of bacteria may, however, be brought about in hastening their elimination by purgatives, or by entangling them and their products by inert substances like wood-charcoal, which is known to have proved most beneficial in indigestion and flatulency—states which are probably due to, or at least intensified by, organisms promoting abnormal fermentations.

It had been hoped that oxidizing agents like chlorinated soda, peroxide of hydrogen, potassium permanganate, and even potassium chlorate would be capable of attacking

[1] *Therapeutic Gazette,* 1891.

bacteria in the alimentary canal. But the last-mentioned passes right through the system into the urine without change, while the others not only disturb digestion, but are rapidly used up by the easily oxidizable organic matters present—*i.e.*, they act on the food before affecting the far more stable bacteria. Much was expected from hydrogen peroxide, but results have been disappointing.

Sulphuretted hydrogen water and sulphites were formerly given with the object of destroying organisms. They are unpleasant, disturb digestion, and do not seem to bring about the desired effect.

Internal Antisepsis.—Although it is difficult to kill the bacteria within the alimentary canal, it is quite feasible to hinder their growth by an inhibitory or antiseptic treatment, and so at the same time to lessen the auto-intoxication produced. If the contents of the stomach were undergoing fermentation by the action of yeast, etc., it would be quite possible to stop the process by means of phenol, creosote, or an essential oil, with a dose so small as not to injure the coats of the stomach. But the same dose would also stop or at least impede salivary, pancreatic, and gastric digestions. Therefore these powerful agents, though occasionally given in capsules, are not in general favour. It has been suggested that the use of condiments such as salt, vinegar, pepper, mustard, and spices is really an instinct founded on their antiseptic action, since many animals resemble man in this respect. The effect of mineral waters, too, depends in a large measure on the antiseptic action of carbonic acid, and not on the alkali, since soda water generally does not contain soda in any efficient quantity.

It has been already pointed out that acids are antagonistic to most bacteria. Dilute sulphuric acid has been preferred in many diseases, especially cholera, on account of the additional advantage of its astringent action. Sulphuric lemonade, made by the addition of the acid, which should be perfectly pure, to sweetened and sterilized water in quantities sufficient to give a marked, but pleasant, acidulous flavour, may be employed freely, and according to all experience with much benefit. Excellent effects have been attributed to the habitual and free supply of a pleasant-flavoured sulphuric orangeade among the employés of the Post Office during several cholera seasons.

It is cheap and innocuous, and is very likely to do much good. Although ordinary lemonade contains citric acid, it is more costly, and is inferior to sulphuric for this special purpose.

The Vienna mixture for choleraic diarrhœa consists of 15 drops of aromatic sulphuric acid (sulphuric acid 1 in 12, with rectified spirit, cinnamon, and ginger) to 1 ounce of sweetened water; to this is often added, under medical advice, 5 or 10 drops of ether and 5 drops of laudanum. The mixture has been much used and highly thought of in Austria, Germany, and France, and by the English Local Government Board.

For intestinal antisepsis neither phenol nor creosote can be employed, being too poisonous and irritating. Betol, however (p. 242), has been successfully used, the β-naphthol produced by its decomposition being comparatively non-injurious. Resorcinol, guaiacol, thymol, and sodium benzoate are sometimes used as internal antiseptics, and in cases of colitis have proved their efficacy by deodorizing the bowel discharges. Sodium sulphocarbolate is also much used. The action of calomel in cases of duodenal indigestion seems to be bactericidal.

Quinine and its source, cinchona bark, probably owe a great deal of their power in fevers to their antiseptic action.

Several of the derivatives of guaiacol, such as benzosol, have been highly recommended. Pheno-salyl (p. 270) is a good preparation for washing out the bladder and urethra.[1] Urotropine as a prophylactic against typhoid fever owes its efficacy to the generation of formaldehyde.

Vaccination.—Vaccination and other preventative measures of inoculation are at present foreign to the scope of the present work, but may properly be regarded as precautionary measures relating to personal disinfection. Modern research seems to indicate that the toxines produced by the micro-organisms of infectious disease are the natural disinfectants for combating the disease, and there seems good ground for believing that progress on these lines will be rapid in the near future. The present absence of definite chemical knowledge as to the nature of these remedies for phthisis, hydrophobia, diphtheria, and similar diseases, renders the

[1] On intestinal antiseptics *v.* Burney Yeo., *Brit. Med. J.*, 1899, p. 1250; Vaughan Harley and Goodbody, *ibid.*, 1899, p. 1254.

subject unsuitable for treatment here, although their investigation from a bacteriological point of view has yielded, without doubt, some of the most valuable and suggestive results obtained in recent years.

Natural immunity is produced either by dissolved alexines or from the resistance of the tissues, whilst acquired immunity is due to the presence of modified bacterial products. The serum of animals vaccinated against cholera and pneumonia appears to have no antitoxic properties, although it is germicidal on the microbe. With diphtheria and tetanus the antitoxin is properly so called, as it is destructive to the toxines secreted by the micro-organisms.

CHAPTER XIV.

PRESERVATION OF FOOD.

History—Causes of change in Food—(1) Oxidation—(2) Reduction—(3) Metallic Contamination—(4) Organisms—Methods of exclusion of the latter—Poisonous Products of Decomposition. Methods of Preservation: Drying—Smoking—Salting—Gases—Injection—Acids—Bisulphites—Glycerine—Experiments with Boric Acid and Formaldehyde—Departmental Committee on Preservatives—Brussels Congress—New South Wales. Cold: Refrigerating Plant. Heat: Effects of Cooking on Bacteria—Canning Processes. Milk: A common vehicle for contagion—Precautions—Sterilization—Pasteurization—Condensed Milk—Butter—Pasteurized Cream—Cheese. Bread and Grain. Brewing and Vinegar Making.

It was early found that perishable solid foods could be rendered more portable and preserved for considerable periods by simple drying. In hot countries hanging in the sun was usually sufficient; in colder ones artificial heat had to be employed. The first taste for smoked provisions probably arose from the practice of suspending meat or fish near the roof where they were penetrated by the vapours from the peat or wood smoke, which greatly increased the keeping properties. The South American "charqui," North American "pemmican," South African "biltong," and the meat dried, pounded, and mixed with fat, which

was formerly much used in Arctic voyages, are well known. Raisins, figs, various herbs, and notably hay, are very early examples of drying applied to vegetable products.

Probably the first discovery of the preservative use of *salt* was accidental, and due to the finding of carcases embedded in the incrustations of the many saline deserts of Asia. Pliny describes salt as "defuncta etiam à putrescendo vindicans, ut durent ita per secula,"[1] and refers to "carnes sale adservatæ," flesh preserved with salt.[2] Columella (de Re Rustica) has "muriâ condire," to preserve with brine.[3] But at periods when fresh food was easily obtained, preservation was not so much a matter of importance, and therefore there are few early allusions to the use of salt, vinegar, and allied substances except as medicines or condiments.

The difference between various salts was confused, and the names given are difficult to identify. Thus in Jeremiah ii. 22, and in Pliny, *nitre* signifies crude carbonate of soda, since called *natron*, and later in Spain *barilla*, and although the real nitre or saltpetre was collected in India before the Christian era, the beginning of its use for reddening salted meats I have not been able to trace.

The Greeks and Romans made great use of salted fish, but mainly as an incentive to the consumption of wine. It was not likely that salting would be employed popularly, since salt was by no means plentiful, as shown by the word "salary" (salarium), or allowance of salt, coming to mean the payment of officials (Trench). Wine was frequently salted, or made with sea-water, with the object of keeping. Olives, samphire, and other vegetables were preserved in brine. Pickles of various kinds, ταρίχη, were used (Julius Pollux, book vi.).

Alum was known to the Egyptians as a drug, and its astringent and preservative action on flesh is mentioned. The effects of sulphur in fumigation are described by Homer.

Boric acid and borax were confused by the ancients with other salts, and valued only as fluxes in the arts. Asiatic borax was first refined at Venice. Boric acid was named by the alchemists "sal sedativus," but without reference to its preservative effect.

[1] *Hist. Nat.*, xxxiii., 9. [2] *Ibid.* xxxiii., 10.
[3] The word *condiment* originally means a preservative, from this word *condire*.

Aromatics, on the other hand, from being used for embalming, were eventually extended to food. These generally owed their properties to benzoic or cinnamic acid or to essential oils. Turpentine from *Pistacia terebinthus* (not from pines) was added to wine in Palestine, and is several times mentioned in the Bible. Among the Romans, *myrrh,* the gum-resin of *Balsamodendron myrrha,* which grew throughout the East, had a great reputation for preventing the souring of wine. Pliny[1] says:—"Lautissima apud priscos vina erant, murræ odore condita." Essential oils, aloes and other bitters were also used.[2]

Bitter herbs were used from the first, and owed their virtues in preventing change partly to their tannin, which coagulated albuminous substances, and partly to essential oils and to alkaloids, which acted as antiseptics. Mugwort (*Artemisia vulgaris*), alecost (*Chrysanthemum balsamita*), and alehoof (*Nepeta glechoma*), derived their Saxon names from their preserving beer; wormwood (*A. absynthium*) was much used for vegetable juices on the continent. Camomile, quassia, gentian, and hop are all bitters of the kind. Acrid substances like pepper were early employed as preservatives, particularly from insects. All these imparted their own strong flavour, and, therefore, their application was limited. "Cassaripe," the inspissated juice of the root of *Manihot utilissima,* is used by the natives of Brazil and the Antilles as a meat preservative.[3]

In northern climates the smoking of meats and fish was always practised, and oak or beech wood smoke was preferred, as these yield more of the preserving agents, acetic acid and creosote. The formation of an "empyreuma," or tarry liquor, from wood was early known, and to hasten the process the flesh was dipped in it before smoking, but in this way an inferior product was obtained.

Glauber in 1650 mentions the preservative power of wood-tar, or "the oily part of the distillation of wood, which is more fixed than the acid," and states that if meat is either simply washed, dried, and laid in strong vinegar, or boiled in a weaker vinegar and set aside in a cool place, it will often keep for several months, and that meat will keep fresh

[1] *Hist. Nat.*, xiv., 13. [2] *Ibid*, xiii., 15; *Palladius*, xi., 14.
[3] *Zeit. oest. Apoth. Ver.*, 1900, 217.

for a considerable time if suspended in a close vessel, on the bottom of which some strong acetic acid has been poured. Fish was "soused," or pickled in vinegar and spices in very ancient times.

Although strong spirit was distilled from fermented juices by several ancient nations, it does not seem to have been applied to preserving solid foods, probably on account of its hardening properties. Even at present, "cherry-brandy" is about its only well-known use in this direction, but for vegetable juices, as cordials, spirit was largely employed, usually with spices.

Oil was used at a very early date for preserving fish and for covering wine, and had mainly the object of excluding air. Both uses are still extant, for wine in Italy, and in tinned sardines.

Not only fruits, but meat and fish have been kept by sugar alone. In Portugal, fish are still preserved by splitting, cleaning, and sprinkling the interior with sugar, and laying out horizontally so that the sugar may penetrate as much as possible. It is said that fish prepared in this way can be kept for a long time with a perfectly fresh flavour, especially salmon, and that one or two ounces of powdered white sugar is sufficient for a 5 lb. fish.

Causes of Change in Food.—1. *Oxidation.*—This is comparatively rare and slow in the absence of microbes. Dilute alcohol is transformed into acetic acid by air when in contact with platinum black, but the process is quicker under the action of the vinegar fungus, *Mycoderma aceti.* As far as is known, simple oxidation never renders substances injurious.

2. *Reduction.*—Almost the only reducing agent that could naturally occur in this connection would be sulphuretted hydrogen, which would involve putrefaction in the substance or in the neighbourhood, and would therefore presuppose the presence of bacteria. It has been suggested that the peculiar taste of certain canned foods depends on the reduction of the fluids by the metal, on the ground that its degree is out of proportion with the traces of metal dissolved, and that it is caused with such extreme rapidity, as, for example, when an apple or fish is cut with a steel knife. In this latter case the taste is often imaginary, as blindfold experiments with apples and fish show that the majority of

persons are unable to detect which was cut with clean steel and which with silver. Of course if the former metal is allowed time to become acted upon, a ferruginous taste is imparted. Zinc gives a different flavour, magnesium gives none; hence the cause would seem to be the metal, not reduction. There is no evidence that a slight reduction would be at all injurious. Sulphites and formaldehyde, if used for preserving, would cause some reduction in unstable constituents of the food.

3. *Metallic Contamination.*—The injury to the taste and colour of vegetable substances coming in contact with iron led to the use of copper vessels for preparing jams and syrups, and even pickles were formerly made in copper vessels. The employment of this metal for vinegar or very acid juices is most reprehensible, as even if the surface is clean, an unknown and often considerable amount of metal finds its way into the food. Mainly through Dr. Hassall and Messrs. Crosse and Blackwell, apparatus of wood, stoneware, and even silver and platinum have displaced copper in making pickles. Enamelled iron should be used for making jams. The presence of copper in preserved peas has been defended on the ground that (*a*) it improved the colour; (*b*) being antiseptic, it increased the keeping properties; (*c*) it was not poisonous in small quantities; but acted as a beneficial tonic. The best authorities regard it as irritant; it is probably cumulative, and it should certainly be prohibited. Lead may be present from the solder, and Hehner has drawn attention to the fact that almost all canned provisions contain tin in solution.[1] Superior goods are put up with oiled paper linings, so as not to come in contact with the metal. The irritant effects of some tinned goods have been attributed to chloride of zinc, which had entered in the soldering; this, and also the dropping in of particles of solder containing lead, have been since prevented by a guard-plate underneath the hole, or by the use of resin for soldering instead of zinc chloride. W. Reuss[2] noticed the presence of lead in preserves contained in tinned-iron canisters. The latter were constructed by bending some

[1] H. Beckurtz (*Apoth. Zeit.*, 1897, Bd. i., p 584) in his analyses of tinned peas, beans, celery, asparagus, truffles, etc., detected tin to the amount of 0·2 to 0·6 grms. per kilo.

[2] *Chem. Zeitung*, 1891, pp. 1522 and 1583.

sheet-metal together, thereby avoiding contamination with lead by means of solder, and hermetically sealed by india-rubber bands. He subsequently traced the lead to these bands, which owed their colour to red lead. On examining red india-rubber bands of French, German, and English manufacture, he found them to contain as much as 60 per cent. of red lead. Many of the india-rubber bands used for sealing pickles, jams, meats, and preserves owe their red colour to sulphide of antimony, and are free from lead, but antimony has not been found in the food itself. In New York, glass vessels have been tried to overcome these difficulties, but, owing to the expense, breakage, and unsightly appearance of some forms of soups and meats, they have not met with much success. For brawn and potted meats earthenware is used. Its weight and fragility are the only disadvantages.

Attempts have been made to coat the inside of the tin with varnish, paraffin, etc., but have not been successful.

If the inside of the tin be much discoloured, or if tinned fruits show a strongly marked crystalline appearance on the interior surface they are unsafe to be eaten. Any discoloration of the contents, or any peculiar odour or taste, should also be distrusted.

4. *Organisms.*—Yeast, moulds, and bacteria can be carried in the dust of the air on to the surface of any exposed food, and there develop fermentative and putrefactive changes. It would be supposed, therefore, that exclusion of air and dust would suffice to preserve changeable bodies, and with this object receptacles exhausted by an air pump and afterwards hermetically sealed have been patented. But the food must be previously collected so as to exclude organisms; or must be sterilized by sufficient heat. It is practically impossible, however, to preserve most alimentary substances in the raw state without the addition of spices or chemicals. Eggs can be preserved for months by keeping them in a pan of lime water, or by dipping them in a cream of slaked lime and water; in each case the shell is rendered impervious by a coating of carbonate of lime, and the albuminous inner lining of the shell is coagulated and rendered aseptic, as can be proved by breaking and examining. Smearing with fat or varnishing gives a bad flavour. Paraffin wax easily peels off, and is expensive.

An immense number of processes have been suggested, but the most successful are lime water, or excluding the air by a coating of vaseline. See an account of extensive trials in Germany, United States Consular Reports, September, 1901. Sodium silicate (water-glass) also gives fair results.[1] Fruit has been kept from decay by a coating of melted wax, when gathered fresh and not quite ripe.[2] B. Ehrlich cites[3] a number of instances in which diseases were conveyed by fruit gathered, marketed, or handled under insanitary conditions, and points out that micro-organisms adhere readily to the surface of fruits. Experiments were therefore undertaken to determine the number and kinds of such micro-organisms. The smallest number were found on blueberries and plums and the largest number on currants and cherries. It was found to be possible to remove the greater number of micro-organisms by washing.

Jams are usually covered with parchment paper sealed down by white of egg; this membrane does not necessarily exclude air, but its tiny holes must be small enough to arrest bacteria and spores of mould. Generally a disc of tissue paper is laid on the jam, when hot, as an additional precaution. It will be found sometimes that mould has grown on the top of this, but has not penetrated to the preserve.

Coating with glue, gelatine, or melted fat has been tried for meat with only partial success. Meat is preserved to a certain extent by membranes such as sausage skins. Electrical methods have been suggested,[4] but have little effect on bacteria except through the heat that may be produced.

Poisonous Products of Decomposition.—It must not be forgotten that as, in the first instance, micro-organisms settle on the surface, unsafe food may present a normal appearance, and consequently be passed by inspectors and others as suitable for consumption, a point in favour of the judicious use in certain cases, and under restrictions, of approved preservatives. Very slight evidences of decomposition in fish are sufficient to indicate the possible presence of toxic products of bacteria, so that fish can never be trusted in the same way that high game and mutton some-

[1] *Chem. and Drugg.*, lii., 704; Strutt, *Chem. News*, 1901, lxxxiii., 268.
[2] Also see use of alcohol vapour, p. 323. [3] *Arch. Hyg.*, 1901, No. 2.
[4] As in patents 7851 and 8301 of 1902.

times are. Van Ermengem states[1] that the toxic ptomaines sometimes found in preserved meats originate from a specific organism, *Bacillus botulinus*. The soluble ptomaine, *botuline*, which it excretes, is said to be intensely poisonous. The ptomaine is destroyed at 60-70° C., and the bacillus at 85°, so thorough cooking is capable of removing the danger. But see the remarks later under Preservation by Heat.

Milk has been shown to be a frequent source of danger, and many epidemics have been traced to its pollution, either through the water supply of the cows, carelessness in the dairy, or in the conditions obtaining between the time when it is supplied by the farmer and when it reaches the house of the consumer. Vaughan has further shown that in addition to the danger of milk containing pathogenic organisms, under certain conditions *tyrotoxicon*, a ptomaine produced by a little known species, has caused several outbreaks of summer and infantile cholera. As the poison is destroyed by boiling, its absence may be assured by this precaution. Vaughan has also demonstrated its presence in cheese, ice creams, and stale fish.

Methods of Preservation.

Drying alone is the subject of a large number of patents, differing only in mechanical details. Expression of water and desiccation leave the fibre and dried juices incapable of putrefaction, but the flavour and digestibility are much impaired. Dried vegetables, soup tablets and desiccated soup are often wholesome and palatable, and keep well in closed tins.

Smoking dries the surface, and also impregnates it with acetic acid, formaldehyde, and creosote. Although the two former eventually volatilize from the food, the surface retains a good deal of the creosote, and undergoes little change except that the fat in time may become rusty or rancid. A great part of this rankness may be removed by putting about half a dozen lumps of freshly-burnt, or re-heated, charcoal in the water in which the meat is boiled. The charcoal removes the odour, but does not thereby render the article wholesome, hence the change must not have gone too far. Smoking has only a surface preservative action, and does

[1] *Amer. Druggist and Pharm. Rec.*, 1898, Sept. 10th, 162.

not reach the interior, so that the ova of trichina, tapeworm, etc., remain undestroyed. In countries like Germany, where smoked sausages are consumed raw, or nearly so, the ravages of these parasites are frequently severe. In England, where thorough cooking is the rule, such epidemics are very rare, still it must be remembered that neither drying, smoking, nor salting secures safety against the ova of parasites. To save time, hams, haddocks, etc., are often cured by dipping in pyroligneous acid, or crude wood-vinegar, with or without brine, or even by being merely brushed over with this solution. Kippers and haddocks are often prepared under most unsanitary conditions, and as the treatment is often far from complete, may be a source of danger.

Salting.—The only inorganic salt that we intentionally and habitually add to our food is sodium chloride, which seems to be necessary for digestion and a natural instinct, as many wild animals are noticed to regularly visit salt deposits, and will lick lumps of salt. It will be noticed that these natural deposits always contain nitrates, and in many cases borax.

There seems to be no direct equivalent of our word "bacon" in the classics. "Perna" (*Plautus*, Curc., ii, 3, 54; *Persius*, "et piper et pernæ, Marsi monumenta clientis"), "petasio" and "laridum" or "lardum," seem to be the nearest. The word "bacon" is old French.

Salting as commercially practised, is a process of osmosis or diffusion; a crystalloid applied externally, either as a solid or in strong solution, diffuses into the interior, while the soluble albuminous matters pass out into the brine. Soluble mineral salts, and sugar, also act as partial desiccators by their affinity for water. The flesh is deprived of a great part of its putrescent constituents, but at the same time loses a corresponding nutritive value (Liebig estimated the loss at one-third to one-half), and leaves nearly insoluble fibrinoids, partially hardened and less digestible, "induratas sale," as Pliny says.[1]

After either smoking, salting, or drying, the characters of fresh food cannot be restored. It was not till the middle of the 19th century that it was discovered that small quantities of certain antiseptics would enable the original qualities

[1] *Hist. Nat.*, xxviii., 20.

to be retained, and prevent decay for a considerable period, with less influence on digestion than the old curing processes.

The quantity of mineral matter introduced in salting is considerable. A mixture of 2 lbs. salt, 2 oz. saltpetre, and 1½ oz. moist sugar is rubbed thoroughly into the meat, which is then kept in a cool place and turned daily, rubbing in fresh salt where required. When the brine, as it forms, is drained away from the meat, the process is called *dry-salting;* if it be allowed to remain on it, it is called wet-salting or pickling. A pickling brine is made with 4 lbs. salt, ½ lb. to 1 lb. sugar, and 2 oz. saltpetre in 2 gallons of water. The liquor, in time, becomes diluted by the meat juices, and is also apt to turn foul, therefore, at intervals, it is boiled down with more of the dry ingredients and skimmed, which has the effect of sterilizing it, and removing albuminous matters. For a fine red colour the saltpetre is increased to about 8 per cent. of the pickling salt. In America it is usual to add to the brine about ½ per cent. of bicarbonate of potash or "saleratus" and creosote sometimes in the proportion of one drop to the gallon.

In this way a high amount of salt, and an appreciable quantity of nitre is consumed with the food. Thus in mild-cured bacon I have found the following percentages:—

	Sodium chloride.	Potassium nitrate.
Raw	4·27 ...	·0083
Smoked	3·34 ...	·0086
Smoked and boiled	2·38 ...	·0065
Smoked and grilled	2·24 ...	·0086

The antiseptic power of salt is decidedly weak, hence the need for large quantities. In many cases brine becomes contaminated with ptomaines. The meat, however, is usually washed before cooking.

Occasionally carbolic acid or phenol has been added to brine; but it is an objectionable antiseptic for food on account of its odour, taste, and poisonous character. *Carbolic paper* has, however, been much used in Europe for packing meats: it is made by mixing 5 parts of paraffin wax, 5 of stearin, and 2 of phenol, and brushing in a melted state over paper.

Preserving Food by Gases—About fifty years ago, Pelouze, from the observation that carbon monoxide was

absorbed by hæmoglobin, forming a compound that was hardly putrescible, devised his process for the use of this gas as a preservative. The meat was cut up into pieces of convenient size, and placed in an atmosphere of carbon monoxide, under pressure. It was then dried in a current of air, and sealed up airtight, or might be kept in a solution of salt or saltpetre, or in "much diluted carbolic acid."

Carbon dioxide, CO_2, has already been dealt with at p. 145.

In May, 1898, I examined a leg of mutton that had been preserved raw in CO_2 since December 2nd, 1897. Although it had lost some of its colour and had softened it had no offensive odour. When either stewed or roasted it was quite palatable and produced no ill-effects. The fat was normal and the cold water extract differed slightly from that of fresh meat, but the broth was much less savoury. The minced flesh when kept for four days simply dried up and became covered with mould, but did not acquire a putrid odour as fresh meat did. Comparative analyses gave (fat excluded):—

	Preserved leg.	Fresh mutton.
Water	71·53	75·19
Soluble albumen and globulins	0·86	2·49
Soluble inorganic salts	1·12	0·95
Insoluble ditto	0·32	0·28
Organic extractives:—Albumoses, peptones and flesh bases	5·44	3·40
Gelatinous matters extracted by water under pressure for 6 hours at 115° C.	2·69	2·26
	100·00	100·00
Total cold water extract	7·42	6·84
Total ash	1.44	1·23

A larger number of bacteria were present than in fresh meat, chiefly consisting of a motile bacillus, not putrefactive, very resistant, and facultatively aerobic.

From this and other experiments it appears that carbonic acid, though generally effective for mineral waters, will not of itself prevent changes in milk or meat.

The vapour of carbon disulphide was proposed in 1878 for preserving meat (p. 138).

Hydrogen Peroxide has been discussed at p. 119. M. Touchard has reinvestigated its action on several bacteria

and fungi, and considers it one of the most useful of germicidal agents.[1]

Injection with various fluids has been often tried. Morgan in 1857 injected a salt and nitre solution through the vessels of recently killed animals to wash out the blood, but the method was not always successful in preventing putrefaction. M. Gannel even injected aluminium chloride: this deleterious salt was intended to be removed before use by soaking for 24 hours in water. It is well known that meat shows a tendency to first become tainted "near the bone" or at the joints. Consequently a practice has arisen of injecting a preservative solution, usually boric acid, into the acetabulum and other joint-cavities to wash out serous accumulations and leave a small quantity of the antiseptic. The method seems successful, and has the advantage of introducing a minimum of the chemical substance.

Acids.—Since the great majority of bacteria grow best in neutral or alkaline solutions, nearly all acids have more or less inhibitive power on putrefaction. Meat has been preserved by immersing repeatedly in dilute hydrochloric acid and drying. When required for use it was dipped in dilute sodium carbonate; only salt was then left. Vinegar and acetic acid have already been referred to.

A "butter preservative," imported into the United States, was diluted phosphoric acid (1887).

Sulphur dioxide, or sulphurous acid (see p. 127), is one of the oldest of the antiseptics, and as produced by burning sulphur was known to all the ancient nations. Wine casks and skins were sulphured. At Augsburg, in 1400, a special law was enacted, forbidding the sulphuring of casks. In the records of the Common Council of London, in 1635, certain wines were pronounced unwholesome, and condemned to be destroyed, because, among other things, they contained "some quantities of sulphur."

Sulphurous acid and the bisulphites absorb oxygen, therefore hinder aerobic organisms from acting, and so retard souring and many changes. They are much used by brewers for casks, and in finings, by makers of lime juice, liquors, and cordials, bottled beers, bottled fruits, sometimes by vinegar makers, and powdered bisulphites by

[1] *Bull. Gén. de Thérap.*, March, 1899.

butchers. The poisonous bisulphite of zinc has been patented for preserving meat.

The quantity of sulphurous acid or bisulphites required to kill or inhibit organisms has been very variously stated. The efficiency is considerable against moulds and ferments, but when used in effective amounts they are apt to communicate a bad taste. In canned goods they are objectionable, as they dissolve the metals.

Salicylic and *Benzoic* acids have been fully noticed, pp. 264 and 268. In many countries the use of the former in food is prohibited. Battershall found that several beer preservatives in the United States consisted of sodium salicylate and borax dissolved in glycerine. The recommendations of the British Departmental Committee on Food Preservatives, 1901, are given later, p. 423.

The benzoates have less taste and odour than the free acid, and in the small quantity that is required they would seem to be an unobjectionable preservative.

The introduction of the sulphonic group usually increases the solubility of organic compounds, diminishes the odour and action on animals, while rather augmenting the antiseptic power; hence many bodies of this class have been introduced as preservatives, such as phenol-sulphonic acid, benzosulphonic (as "sodium sulphobenzoate"), "saccharin" (benzoylsulphonic imide), and others. See Index.

Fluorides are described, p. 105. In comparative experiments I have satisfied myself that they are about equal to the corresponding benzoates in molecular preservative property (p. 421).

Glycerine has been much used, but mainly as an adjunct to, or solvent of, other preservatives, and for disguising taste. A. Schmidt[1] states that glycerine, alum, and sodium bicarbonate are added to beer, and that "beer poor in extractive and alcoholic constituents is liable to become sour, a defect which is remedied by the use of alkalies and chalk, the resulting disagreeable taste being disguised by means of glycerine." It is, however, only a preservative in strong solutions, weaker ones undergo various fermentations (p. 327). Hams and dried fish have been soaked in 20 per cent. glycerine for preserving, but its hygroscopic property has militated against its use in this direction.

[1] *Archiv. der Pharm.*, 1885, vii., 392.

Molecular Proportions.—It is evident that in contrasting a series of salts of the same acid, a solution containing in the same volume an equal number of molecules of the salt must include in each case an equal weight of the acid groups; any difference in the behaviour will then be due to the variation in the base. Similarly by taking molecular proportions of the different salts of one metal, the influence of the molecular weight of the different acid groupings upon the retardation in the development of the putrefactive organisms may be traced.

In some experiments in this direction I have determined the retardation in the souring of milk by molecular proportions of different salts, and find that the alkaline metals, potassium, sodium, and lithium, show great resemblance, whilst an equivalent of ammonium, probably owing to its decomposition, distinctly promotes the production of acid.

With regard to the acid radicle, chlorides are conducive to souring—common salt especially not only not hindering, but actually often accelerating the decomposition. Nitrates, on the other hand, have an inhibitive effect. Benzoates and fluorides have a decidedly preservative action, which for short times is greater in the former, and is specially marked in benzoic acid. Probably owing to their decomposition, the effect of benzoates wears off in longer times, whereas that of fluorides remains fairly permanent.

Boric Acid and Borates.—The knowledge of the preservative action of these compounds is, as we have seen, quite of modern date. A great variety of boric mixtures have been introduced under different names, and are very largely used at the present time, especially for the preservation of milk, cream and butter (see p. 143).

Formaldehyde (p. 295), has been applied successfully, either in solution or vapour, to the preservation of milk, meat, and other articles of food. It may even exist naturally in food, as Pollacci has separated it by distillation from leaves which have been exposed to light and macerated in water.[1] The author[2] with Dr. Foulerton investigated (1) the quantities of boric acid and formaldehyde necessary for preserving milk, and (2) the capacity of such amounts to occasion injurious effects, owing to the general opinion that the

[1] *Chem. Centralblatt*, 1899, ii., 881.
[2] *Public Health*, 1899, May; *v.* also Foulerton, *Lancet*, 1899, pp. 1427, 1571.

possibility of comparatively large doses being present in foods rendered them injurious to health. But milk is practically the only article of food which is consumed in sufficiently large quantities to cause the addition of preservative to possibly assume toxic proportions. In the paper referred to we stated that 1 part in 2,000 of boric acid mixture (4 grains to the pint) and 1 in 50,000 of formaldehyde were quantities of preservatives sufficient for keeping milk sweet for a period of 24 hours even in warm weather.

These quantities cause some slight retardation when the examination is made before the digestion is completed, that is, after equal times, but a little longer time sufficed to ensure the complete digestion of the preserved food. It is also important to recollect that both preservatives have practically no effect upon the digestion of casein, and therefore, in a milk diet, their effect is less marked than when the preservatives are used with meat or starchy foods. The following experiments show that the influence of these preservatives in the above quantities is comparable to that of condiments, or alcohol or tea, upon starch digestion :—

Breadcrumb 5 grm. with 50 c.c. water, exposed to Action of Ferment for Half an Hour.

		ZYMINE. Maltose produced :—		SALIVA. Maltose produced :—	
1	Nothing added	0·5395	= 100	0·707	= 100
2	Formic aldehyde, 1 in 50,000	0·477	= 88·5	0·672	= 95
3	Boric acid, 1 in 2,000	0·423	= 78·5	0·607	= 86
4	Malt vinegar, 2½ c.c.	0·258	= 48	0·1647	= 23
5	Salt, 0·2 gramme	0·52	= 97	0·70	= 99
6	Worcester sauce, 1 c.c.	0·5	= 93	0·57	82
7	Alcohol, 5 per cent. (claret and water, 25 c.c. of each)	0·47	= 88	0·701	= 99
8	Tea, ⅛ gramme infused in 50 c.c. of water...	0·491	91	0·650	92

In the pancreatic digestion of casein, no difference could be observed in the amount of casein digested with and without formaldehyde, whereas an addition of a small quantity of infused tea, claret, or Worcester sauce to the milk reduced the amount of digested casein to a small but noticeable extent. The conclusion is that the small amount of preservative has actually less effect than these ordinary additions to food.

Other investigators have also found that many ordinary food substances have an effect on digestion quite comparable with that of these small quantities of preservatives. Thus E.

Laborde digested coagulated egg-albumen with pepsin or trypsin at 40° C. for three to four hours, alone, and in presence of various bodies allied to the alcohols. He finds that while some of the substances present in beverages, such as isobutyl alcohol and glycerine, are distinctly favourable to both peptic and pancreatic digestion, ethyl alcohol, lactic and tartaric acids retard them. According to this author, dextrose assists pancreatic, but delays peptic, digestion.

An agitation against preservatives caused a Departmental Committee to recommend:—

(*a*) That the use of formaldehyde or formalin, or preparations thereof, in goods or drinks be absolutely prohibited, and that salicylic acid be not used in a greater proportion than 1 gr. per pint in liquid food and 1 gr. per lb. in solid food. Its presence in all cases to be declared.

(*b*) That the use of any preservative whatever in milk offered for sale in the United Kingdom be constituted an offence under the Sale of Food and Drugs Act.

(*c*) That the only preservative which it shall be lawful to use in cream be boric acid or mixtures of boric acid and borax, and in amount not exceeding 0·25 per cent. expressed as boric acid. The amount of such preservative to be notified by a label upon the vessel.

(*d*) That the only preservative permitted to be used in butter and margarine be boric acid or mixtures of boric acid and borax, to be used in proportions not exceeding 0·5 per cent. expressed as boric acid.

(*e*) That in the case of all dietetic preparations intended for the use of invalids or infants, chemical preservatives of all kinds be prohibited. No fresh legislation has, however, been passed since these recommendations in England, and in the United States similarly the matter is still under discussion.

At the International Congress on Hygiene at Brussels, in 1903, resolutions were passed in favour of the total abolition of preservatives in all kinds of food, notwithstanding that from time immemorial admitted harmless preservatives, *e.g.*, salt, sugar, and hops have been regarded as legitimate articles in food supplies, and it is obvious that any drastic recommendations of this character cannot form part of any legal enactments in any country. In New South Wales the following new regulations under the N.S.W. Public Health

Act, 1902, came into operation in June, 1903. The antiseptics mentioned are formic aldehyde, boric acid, hydrofluoric acid, sulphurous acid, benzoic acid, salicylic acid, and preparations of these substances. No more than one antiseptic is allowed to be used in any one sample of food. Antiseptics are practically prohibited in the following articles, only $\frac{1}{10\,0\,0}$ gr. per lb. or pint being allowed, or 1 part in 7,000,000: Aerated waters, butter, potted foods, cream, cheese, condensed and concentrated milk, canned foods, conserves, cordials, condiments, foods (canned and bottled), fruits (preserved or fresh, and their products in general), fish (fresh), hop-beers, jams, jellies, milk (including condensed and concentrated), preserved fruits, pickles, sauces, syrups, temperance drinks in general, and vinegars. The preservatives allowed are: In beer, cider, and perry, sulphurous acid $1\frac{3}{4}$ gr. per pint; in flesh foods and their products, sulphurous acid $1\frac{3}{4}$ gr. per lb.; in preserved fish, bacon, and ham, sulphurous acid $1\frac{3}{4}$ gr. per lb., or boric acid 10 gr. per lb.; in milk or cream, not for consumption as such, boric acid 10 gr. per pint; in butter, nothing in Regulation 27 is to authorize the mixture of boric acid with butter, but Regulation 28 reads, "Boric acid may be mixed with butter in proportions not exceeding 35 gr. per lb." Labels.—Food containing an antiseptic must be labelled on the outside of the vessel or parcel, with the words that follow, on a white ground in black letters not smaller than $\frac{1}{8}$ inch—

This food is mixed with , and contains grains of to the { pint. / pound.

The blanks are to be filled with the name and quantity of the antiseptic or antiseptic preparation.

Cold.—Although it has already been shown (p. 24) that many micro-organisms are extremely resistant to cold, various methods of refrigeration are largely employed for preservative purposes. In Russia and Canada carcases are buried in frozen earth from November to May. Fish and poultry are constantly brought to town packed in ice, and ships fitted with refrigerating apparatus bring meat from Australia and America. One of the earlier forms of cooling plant is Kent's downward draught method, in which the cooled air being denser descends from the ice-chambers and

passes round the meat. It has been found in practice that it is not absolutely necessary that the meat should be perfectly frozen, a low temperature approaching freezing point is all that is required for temporary preservation. In Gamgee's process the rapid evaporation of sulphurous acid, aided by pumps, produces intense cold, circulating by glycerine and water through pipes. Liquid ammonia is also used in a similar way.

Very large refrigerating chambers are now constructed for the storage of perishable articles. Walls and roof are insulated by an inch of hair-felt between two thicknesses of deal boards joined very closely and with an air-space separating them from the building. The floor is rendered a non-conductor of heat by two layers of deal separated by a layer of finely divided charcoal. Machines are now employed to effect refrigeration by the evaporation of liquid carbonic acid, which when being converted from a liquid to a gas absorbs a very large amount of heat, this heat being taken up from brine (a solution of chloride of calcium and water), which is thus brought to a very low temperature without freezing, and then circulates in pipes throughout the chambers to be cooled, and also cools the inlets of fresh air. The carbonic acid gas after performing its work is drawn into a compressor driven by the steam engine, and compressed up to such pressure as is necessary to liquefy it. It is then conducted to coils of pipe forming the condenser, outside which coils water is circulated, and after being cooled till it liquefies it returns in the liquid state to the evaporator. The carbonic acid is therefore in a closed cycle, the same material being used over and over again. The brine is circulated by means of pumps throughout the brine pipes, or rather grids of brine pipes, which are welded by the electric process into the form of grids, thus avoiding the necessity of a large number of joints in the cold chambers. This brine, after picking up heat in the chambers, returns to the machine to be re-cooled. Owing to the large amount of brine in the pipes in the chambers the action of refrigeration is continued for long after the machines are stopped, and as these brine pipes are placed over the ceilings of the chambers, the cold air falling from them produces a brisk circulation of air in the chambers. The apparatus is safer in case of leakage or accident than those using sulphurous acid and ammonia.

Preservation by Heat.—The conditions under which heat alone, or heat with steam, will sterilize have already been discussed in Chap. III. Articles of food always contain moisture, so that the conditions present here are heat and steam. In frying, the oil or fat reaches 160 to 180° C. (the temperature at which bread crumb turns brown), so that sterilization is usually effected. In canned meats a temperature over 100° C. is used, hence it is probable that the whole of the food is heated to that degree. But in cooking joints Dr. Vallin[1] showed that the interior frequently attained only 54 to 60° C., or even less, and in long cooking only about 70° C. Dr. Fiore injected meat with anthrax bacilli, cooked it in various ways, and then tested the product by inoculating animals with the juice. He obtained, in roasting, a temperature of 60 to 65° C., and found that the bacilli were not killed unless the cooking had been very complete, and that the spores were not killed by a much higher temperature than is used in most countries for roasting meat. He concludes that prolonged boiling is the most favourable method of cooking for completely destroying pathogenic germs. Vallin agrees with Fiore as to the danger of too much reliance on cooking, and the need of great vigilance in the supervision of meat supplies.

M. Appert, of Paris, in 1810, first introduced the process of heating provisions in vessels which could be hermetically closed, so that the steam should drive out the air and a vacuum be produced. This is clearly seen by the fact that the ends of tins which are in proper condition are concave (they may even collapse), and that there is an inrush of air when they are opened. Unless these signs appear, the tin is bad and the contents must not be eaten. All tins are examined in the warehouse, and such as are "blown," *i.e.*, convex at the ends, owing to gases from decomposition inside, are rejected. Collapsed or crushed tins (which are sometimes offered cheap) are also dangerous, as, in the sharp bending of the tin, holes are apt to be formed. There are several processes for canning foods:—

1. *The Chloride of Calcium Process.*—The tins after being filled have the lids soldered on, leaving a pin-hole for escape of steam. They are immersed to two-thirds of

[1] *Revue d' Hygiène*, Sept., 1897.

their depth in a bath of calcium chloride solution, which boils at a higher temperature than water, heated to from 127° C. to 132° C. for one to three hours, and the hole closed by a drop of solder.

2. *The Aberdeen Process.*—The tins are placed in a bath as before, but they are entirely closed. During the heating they are raised at times by a frame, opened to let out air and vapour, so that the tin does not burst, closed again and the heating continued. This is repeated two or three times, according to the size and substance. The pressure within is judged by the forcing out of the ends. Superheated steam is used by some firms instead of salt baths; it is rather more difficult to manage, but leaves the tins clean. This process, which is known by the tins having two or three blow-holes, presents the advantage that more of the natural moisture and flavour are retained. It has superseded the former process in Scotland, Australia, South America, and New Zealand.

3. *Jones's Vacuum Process.*—The tins are packed quite full, and soldered up except a small hole, with a little quill tube, in the top. The bath contains ninety-six 2-lb. tins. Along the centre of the bath runs a tube with twelve taps, each of which carries eight stuffing boxes connected with the tubes. By a fan or pumps a vacuum is created, and the bath is heated gradually to 100° C. The fluid in the tins, under the diminished pressure, boils at about 38° C., so that the steam and air are carried off at a low temperature. After a time the exhaust taps are turned off. The tins then contain no air, and are full of steam. The cooking is continued for two hours at 121° C., letting off the steam occasionally as the pressure increases.

4. *Salzer's Baltimore Process.*—Meat is subjected to dry steam and compressed in moulds, then wrapped in paper or other material, coated with plaster of Paris, and embedded in a heated fat such as suet or lard, in a can or in metallic foil, with certain precautions.[1]

5. In Germany, and to a certain extent in Italy and France, the dangerous and objectionable custom is prevalent of eating meat in the uncooked state, simply smoked or pickled. Raw hams and bacon only smoke-dried, Gotha

[1] Patent No. 11,988, 1892.

sausages, and even chopped raw steak with bread crumbs and onions are commonly consumed. This practice necessitates that the meat in the markets should be rigidly inspected, and hundreds of carcases are seized and destroyed. With the idea of saving this confiscated diseased meat for food, W. Budenberg, of Dortmund, invented a flesh sterilizer, in which the disease germs are killed by steam under pressure.

It consists of a large iron cylinder, one end of which opens on hinges and closes hermetically against packing. Steam at a pressure of half an atmosphere (112° C.) is injected at the top, circulates round the movable iron shelves on which the pieces of meat are placed, and escapes to a condenser through a tube at the bottom, or can be led into a fireplace to burn any unpleasant vapours from the meat. The temperature can now be raised to 127° C. by letting in steam of 2½ atmospheres; after two or three hours' heating all germs of disease are destroyed. The fat and liquor are drawn off separately below. The fat can be used, the liquor is thrown away. At a higher temperature the meat is much disintegrated and dried, but is still digestible and fit for the food of animals, dog biscuits, etc. The temperature of the interior of the largest lumps of flesh, as registered by a maximum thermometer, remains steady at some degrees over 100° C. The loss of weight is from 40 to 50 per cent.

In some cases, where the apparatus is only used as a meat-steamer to save large quantities of meat from being lost by putrefaction in summer, it can be worked throughout at half an atmosphere of steam pressure. At this lower temperature the meat is as juicy and savoury as in ordinary cooking. The interior of the pieces reaches a temperature of 100° to 120° C., so that it can be sold for eating without hesitation. The inventor states that the sterilization at the higher temperature was found by experiment to be perfect.

6. *G. Hartmann's Process*[1] is on the principle of fractional sterilization and consists of three steps. The first consists in subjecting the preserves to a temperature of 100° to 120° C. for a short time; the second in keeping them for some days at a temperature of 20° to 30°, when any germs which have not been destroyed in the primary sterilizing process develop. These are then killed by a final sterilization.

[1] Patent No. 14,601, 1892.

Milk.—A number of pathogenic organisms find milk a favourable place of growth, so that infection of different kinds can be carried by it, and several epidemics have been traced to this cause.[1] Hence the recommendations that milk should be boiled, and the necessity for extreme cleanliness in dairies. Infectious disease occurring on the farm must, under heavy penalties, be instantly reported, and the supply of milk discontinued until the case has been removed and the buildings properly disinfected. Milk cans should be washed and scalded as soon as possible after use, drained and dried in a place free from dust, and kept covered till wanted. Removing any stale smell by charcoal is not a safe proceeding, as the odour is a sign that the cleaning has not been thorough; in such a case the can should be thoroughly steamed, and then washed. Water from ponds or contaminated wells should never be used for washing vessels that are intended for milk; as this has originated many cases of zymotic disease, and the purity of the supply should be periodically tested. Strongly smelling disinfectants cannot be employed for dairies, since milk is so particularly absorbent of odours. Budde has recently advocated peroxide of hydrogen as the best agent for this purpose. Formaldehyde is now largely used in this country and Australia. It is to be regretted that jets of steam are not more extensively used for cleaning milk vessels; it would be easy to fit up an apparatus for this treatment at railway stations, where the cans could be systematically cleansed before going to the farms.

Thorner[2] has estimated the acidity requisite to coagulate milk on warming as corresponding to 0·207 per cent. of lactic acid, but I have found the coagulating point somewhat higher than this, as the coagulation is not very marked even when the acidity is 0·23 per cent., and I believe that when the acidity exceeds 0·25 per cent. of lactic acid the milk would be considered sour and unfit for sale.

The methods of milk preservation may be divided into four groups:—

1. *Injection of various gases* has been already dealt with at p. 144.

[1] As to the occurrence of tubercle bacilli in milk, butter, and margarine, see Dr. Annett, *Lancet*, Jan. 20th, 1900.

[2] *Lancet*, January 27th, 1900.

2. *Addition of preservative solutions* has been treated in the chemical section, and also incidentally in the present chapter.

3. *Sterilization by heat.*—Milk can be kept for an indefinite time by heating it under pressure to 120° C., closing it whilst hot with sterilized stoppers, and storing it in a cool place. If exposed in a warm situation after this, the casein is apt to undergo some molecular change, by which it clots into granules, or even sets almost solid, but no putrefaction ensues. According to Wroblewski[1] sterilization of milk causes the conversion of a little of the milk sugar into caramel, the formation of a trace of lactic acid, the coagulation of albumen, and a slight alteration in the casein, but does not lessen the digestibility. Duclaux kept milk for five years in a vessel from which he had previously exhausted the air and heated the contents to 120° C.

4. *Pasteurization* is a partial sterilization at a temperature high enough to kill pathogenic organisms and to prevent change for a moderate time, without seriously affecting the physical qualities of the milk. The International Congress of Hygiene, 1903, declared that milk of which the origin and conditions of production were unknown, should be considered as dangerous for public supply, and must be submitted to heat before consumption. When properly conducted such heating removed any pathogenic properties without injuring sensibly the food value. Three methods were distinguished:

(*a*) In simple ebullition as practised domestically milk is raised to 95—98° C. for a short time and then kept above 80° C. for 15 to 17 minutes; this destroys *B. tuberculosis*, the most resistant of the ordinary pathogenic forms occurring in milk, provided the pellicle which forms on the surface of the fluid be removed, as this protects the tubercular organisms. The milk should be allowed to cool in the vessel in which it is heated.

(*b*) In domestic pasteurization by apparatus of the Soxhlet type, bottles containing the milk are placed in water which is heated to boiling and then cooled, the operation lasting about 45 minutes. The bottles are closed by spring stoppers with rubber rings, so as to allow the escape of vapour while heating and to close the vessel hermetically on cooling.

[1] *Oest. Chem. Zeit.*, 1898, 1., 5.

On inverting the bottle and giving it a smart tap, a sharp click should be observed, indicating that a partial vacuum has been formed.

(*c*) Industrial pasteurization on the large scale at 85° to 90° C. According to Henseval and Mullie, in Denmark, cream is heated to 85°, but in Belgium only to 70° or 75°; pasteurization improves it for keeping and for making butter. As milk is a somewhat viscous liquid, and does not conduct heat freely, it is kept in circulation through coils or plates, and the regenerative principle is frequently adopted.

The Congress agreed that the methods (*b*) and (*c*) assured the destruction of tubercle bacilli but did not sterilize the milk, which must be consumed within the following 24 to 48 hours. The favourable influence of agitation during the process was also recognized.

In any system of milk sterilization a certain variation of temperature is liable to occur, and it is therefore important to leave a margin above the theoretical minimum of

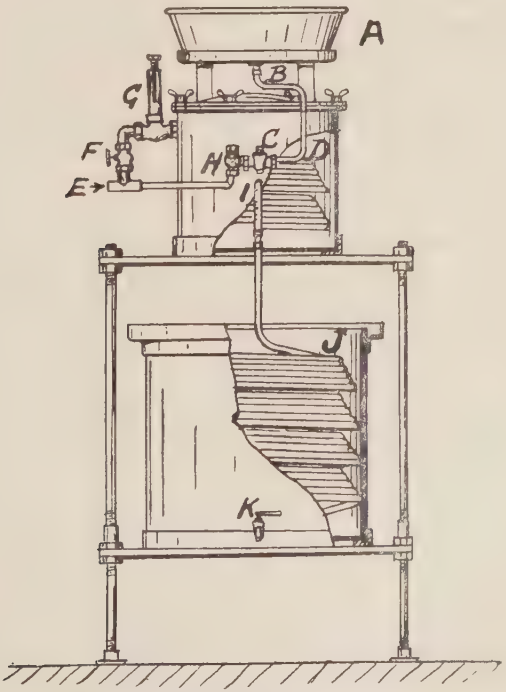


Fig. 22. Equifex Milk Sterilizer.

"sterilization," especially where the process is intended as a safeguard against disease. The Equifex milk sterilizer (Fig. 22) is based on a long series of experiments by Dr. Pakes, and the apparatus has been employed for some two years in treating the entire milk supply at Guy's Hospital. It consists essentially of coils through which the milk flows, the upper part of the coils being in contact with steam under slight pressure and the lower part with water (iced if necessary), the whole process proceeding in a single run of coils without exposing the milk to the air until it has been cooled to practically atmospheric temperature. The net outcome is that tested by a large variety of the most delicate palates with unboiled milk as a control, and no indication as to the identity of the samples, the altered flavour which has hitherto been found inevitable even in pasteurizing processes at lower temperatures is in this case avoided. The arrangement includes means for thoroughly cleaning the coils with hot or cold water, with or without soda, at the end of every day by simply turning a cock.

Condensed Milk.—The process was invented by De Leinac in 1852, and modified later by Borden of New York, who introduced vacuum pans for concentrating the milk without burning. In 1866 the Anglo-Swiss Company started Borden's process on a large scale. The milk is brought in every morning by farmers, who are kept under very careful supervision as to cleanliness of surroundings, and absence of disease. It is tested, mixed, and heated in a bath, with the addition of pure white sugar, then run into the vacuum pans (closed copper vessels from which the air and steam are exhausted), and evaporated rapidly at a low heat for two or three hours, till it is of the consistence of honey. It has been kept practically unchanged for upwards of twenty years. Great cleanliness is of course necessary in the process, and the tins must be sterilized by a jet of steam. If there be any imperfection in the process, or if the tin be not properly sealed, the milk becomes solid and cheesy. If too highly concentrated, the milk-sugar crystallizes, and the preparation becomes gritty.

Condensed milk is perfectly wholesome, but the balance of its food-value is disturbed by the enormous proportion of sugar, about 50 per cent. For this reason it is unsuitable for infants. The directions on the tin as to dilutions are

frequently misleading—1 in 5 or 6 for adults, and 1 in 12 for infants—as the concentration is only 1 to 3 or $3\frac{1}{2}$. Brands such as the "Viking," containing no added sugar, have been introduced.

Butter.—The production of sterilized butter has not been entirely successful, owing to the fact that the proper sterilization of the cream is prevented by the necessary changing of the receptacles during the manufacture. The cream is in consequence brought in contact with numerous surfaces, and is necessarily subjected for a considerable time to the action of the air. The demand for sweet cream butter is not great, and the flavour of the commercial product is due to a "ripening" of the cream caused by certain bacteria which in the larger dairies are now scientifically selected and controlled. The lactic bacteria, by producing acid, check the development of other organisms which may produce injurious fermentative changes. In Europe, the conclusion has been very general that butter produced from pasteurized cream, with the use of special bacterial cultures as starters of the ripening, is superior to that made from unpasteurized cream.[1] We have seen that this opinion was endorsed at the Brussels Congress of Hygiene, 1903. In America, however, according to Conn,[2] the tests do not seem to have been so favourable to the pasteurized cream, as it does not produce so high a flavour.[3]

E. E. Ritsert[4] points out that, notwithstanding the occurrence of most diverse micro-organisms in rancid fats, both aerobic and anaerobic germs die when added to the fresh undecomposed fat, from which it is inferred that the change is not initiated by them. He also found that under the influence of sunlight, which killed the germs, the rancidity was produced more rapidly. Experiments were therefore made with sterilized lard –(1) protected from access of air, but exposed to sunlight, to diffused daylight, and kept in the dark; (2) with access of air, exposed to the sunlight, and kept in the dark; (3) in atmospheres of moist and dry oxygen, carbonic acid, nitrogen, and hydrogen. As a

[1] Lunde, *Centr. f. Agric.*, 1892, p. 554; Steiner, *Milchzeitung*, 1901, p. 401; Marcas and Henseval, *Rev. Gén. de Lait*, 1902, p. 387.

[2] *Bacteria in Milk and its Products*, Rebman, 1903.

[3] *Bull.* xlv., *Pennsylv. Agric. Exp. Sta.*, 1898.

[4] *Pharm. Zeitung*, Sept. 13, 1890, p. 579.

general result it may be stated that the result favourable to the production of rancidity proved to be the action of light during contact with air, the change being induced the more rapidly the more intense the light. Thus it was found that sterilized lard, either moist or dry, when kept from contact with air in sealed tubes, remained free from rancidity for two months, even though exposed to sunlight and warmth. Oxygen, both dry and moist, was absorbed freely in the light, the fat becoming strongly rancid in one month; but none was absorbed in the dark, the fat remaining quite fresh. Nitrogen and hydrogen were not absorbed in any case, and the fat remained unchanged. Carbonic acid was absorbed in the light, and to a less extent in the dark, but the lard only acquired a tallow-like taste, and no odour.

Since butter as ordinarily made entangles about 10 per cent. of water, containing some of the butter-milk, partially preserved by salt, no external application of an antiseptic can be depended on.

Cheese, as is well known, soon undergoes putrefactive changes, without apparently rendering it unwholesome. Antiseptic, or, better, aseptic, wrappers of close canvas, soaked in boric acid and boroglyceride (p. 142) are here of value, and unobjectionable, as the rind is not eaten. They may prevent the access of the organism producing "tyrotoxicon" (p. 415), which is the cause of poisonous cheese. Milk which has been heated forms a less solid clot with rennet, and Dr. Tjaden stated at the Brussels Congress that in his experience after treatment at 85° C. there was no difficulty in ulterior applications, except that the fabrication of hard cheese with it had not been at present satisfactory. Klein and Kirsten[1] showed that milk which had been heated for 15 minutes at 75° C. scarcely loses any of its capacity of being converted into cheese, but that an addition of calcium chloride shortens the time required by the rennet to coagulate the milk. The quantity recommended is 1 in 5,000. After the milk has been heated to 85° C., twice the amount, and after 100° two and a half times the quantity, will be required to restore the coagulability by rennet. The salt is innocuous. The author some years ago found similar results.

[1] *Chem. Zeit. Rep.*, xxiii. [6], 51.

Wheat and other kinds of grain are subject to the attacks of numerous fungi, such as ergot, mildew, etc., which render the flour prepared from them unwholesome. The common remedy is to pickle with sulphate of copper before sowing. Although the quantity of copper which passes into the food is infinitesimal, it would be better if a less poisonous disinfectant could be used. Chloride and acetate of aluminium have been well spoken of; they must be freely diluted, say 1 in 500, or germination is checked.

Bread acquires from the air germs of all kinds, and under certain conditions becomes poisonous. Hence the use of a covered bread-pan, kept scrupulously clean and free from stale crusts, etc., should be insisted on. In the early part of 1894, Dr. Waldo drew attention to the unsanitary state of London Bakehouses. Filth, communication with drains, privies in direct proximity, and personal contamination from the work-people were discovered in a number of cases. Places where the food of the people is prepared should be above ground, in strong daylight (the fatal effects of light on bacteria have been before mentioned), well-ventilated, and clean. Much more supervision should be exercised. It is almost useless to combat bacteria when they are allowed to multiply in the daily food. The London County Council has issued regulations on the subject, and recent legislation has greatly improved matters. Dr. Waldo and Mr. Welsh also showed that organisms and their spores are not destroyed by the ordinary process of baking. They obtained thirteen species of organisms from the centre of recently baked loaves from bakeries in different parts of London. Microbes withstand a long exposure to a much higher temperature than that to which the centre of the loaf is exposed, and there is no reason to believe that even the greater number of the bacteria in the loaf are killed. They also found that tinned and small loaves were often sterile, and conclude that the number of bacteria in loaves bears a direct relation to the dirtiness of the bakehouses. Flour undergoes in unsuitable warehouses a rapid change, and it has been suggested as the cause of many cases of outbreaks of disease, especially of intestinal character. In Bristol the number of such cases directly diminished *pari passu* with the activity of sanitary interference with the dirty bakehouses of the town.

Brewing, and other fermentation industries, such as vinegar making, as being dependent to a great extent on the action of definite organisms, demand scrupulous cleanliness and constant examinations by the microscope to exclude "wild yeasts" and injurious bacteria. The uses of antiseptics and disinfectants at various points has been already discussed under sulphites, ozone, formaldehyde and other agents. Seifert investigated elaborately the action of the two last mentioned, and also of ammonium fluoride, on different fermentations.[1] Lindner[2] drew attention to the frequent infection of the articles by means of the wooden plugs or bungs of fermentation vats and storage casks. Wild yeasts and bacteria penetrate the pores of the wood more quickly than culture yeasts on account of their smaller size, hence there is a kind of selective separation. Plugs should be sterilized by boiling, or should be properly varnished or paraffined over their entire surface.

CHAPTER XV.

LEGAL STATUTES AND REGULATIONS.

The subject of this book is a part of the general legislation on Public Health which has been enacted during the last few years. The duties of disinfection are generally entrusted to the Medical Officer of Health who superintends the work of his inspectors. Formerly powers were much more limited than they are at present.

By the Public Health Act, 1875, the following provisions against *infection* were enacted:—

Where the Medical Officer of Health or any other legally qualified medical practitioner certified that the cleansing and disinfection of any house or part thereof, or of any articles

[1] *Chem. Centr.*, 1899; i., 2, 134. *Woch. f. Brau.*, 1902, xix., 289.

therein, would tend to prevent or check infectious disease, it was the duty of the local authority to give notice to the owner or occupier of the house in question requiring him to do the necessary work within a specified time. The person on whom the notice was served was liable on default to a penalty of 1/- to 10/- for every day during which he continued to make default, and the Local Authority was required to execute the necessary work, and recover the expenses incurred from the responsible party.

If from poverty or other reason the person responsible was unable to carry out the requirements of the local authority, the latter might, with his consent, carry out the necessary work at their own expense (section 120).

Any local authority might direct the destruction of any bedding, clothing, etc., which had been exposed to infection from any dangerous infectious disease, and might give compensation for the same (section 121).

The local authority might provide a proper place with all necessary apparatus and attendance for the disinfection of bedding, etc., and might there disinfect any articles free of charge (section 122).

They might also provide and maintain a carriage suitable for the conveyance of infectious patients, and pay the cost of conveyance of such patients to a hospital or elsewhere (section 123).

Any person suffering from a dangerous infectious disorder who was without proper lodging or accommodation, or lodged in a room occupied by more than one family, or was on board any ship or vessel, or who was lodged in any common lodging-house, might, on the certificate of a legally qualified medical practitioner, be removed by order of any justice to any suitable hospital or place provided within a certain convenient distance. Any person wilfully disobeying or obstructing the execution of this order was liable to a penalty not exceeding £10 (section 124).

Regulations might also be made by any local authority for removing to a hospital persons brought within their district by any ship or boat, who were infected by a dangerous infectious disorder. Any person who—

1. While suffering from any dangerous infectious disorder, wilfully exposed himself without proper precautions in any street, public place, shop, inn, or public conveyance,

or entered any public conveyance without previously notifying it to the owner, conductor, or driver, that he is so suffering; or,

2. Being in charge of any person so suffering, so exposed such sufferer; or,

3. Gives, lends, sells, transmits, or exposes, without previous disinfection, any bedding, clothing, rags, or other things which have been exposed to infection—

Was liable to a penalty not exceeding £5, and must also pay the amount of any loss or expense incurred in disinfecting the public conveyance which has been entered.

Every owner or driver of a public conveyance must immediately provide for its disinfection after it has been used, to his knowledge, by an infectious person, or was liable to a penalty not exceeding £5 (section 127).

Any person knowingly letting for hire any house or part thereof, in which has been any person suffering from infectious disease, without proper disinfection to the satisfaction of a qualified medical practitioner, was liable to a penalty not exceeding £20 (section 128).

Any person who, when letting a house or part thereof for hire, knowingly made a false answer as to the occurrence of a case of infectious disease within six weeks previously, was liable to a penalty not exceeding £20, or to imprisonment not exceeding one month (section 129).

The General Order of Local Government Board for Preventing the spread of Cholera, July 12th, 1883, contained the following regulations:—

1. Every ship is deemed infected with cholera in which there is, or has been during the voyage, or during the stay of the ship in a port in the course of the voyage, any case of cholera.

Regulations as to Detention.—2. If any officer of customs, on the arrival of a ship, ascertains, or has reason to suspect, that the ship is infected with cholera, he shall detain the ship and order it to be moored or anchored in such a position as he may direct.

3. No person must leave the ship while thus detained.

4. The officer thus detaining any ship must give immediate notice to the sanitary officer of the place where the ship is detained.

5. Such detention shall cease as soon as the ship has

been duly visited and examined by the Medical Officer of Health, or if the ship is found to be infected with cholera, as soon as it has been moored and anchored in pursuance of Article 10 of this order. The examination must be commenced within twelve hours of the giving of the notice as aforesaid, otherwise the ship shall be released from detention.

10. The master of any ship so certified to be infected with cholera, shall moor his vessel at the place fixed for that purpose under Article 6, and she shall remain there until the requirements of this order have been duly fulfilled.

17. All articles soiled with cholera discharges must be destroyed, and all clothing and bedding shall be destroyed or disinfected.

18. The ship must be disinfected and every article therein, according to the directions of the Medical Officer of Health.

By the Merchant Shipping Acts the use of lime juice as a precaution against scurvy on long voyages has been made compulsory for many years, and by the same Acts captains are required to destroy the clothing and bedding of cholera patients before the ship enters an English port.

The Committee on Steamship and Steamboat Sanitation of the American Public Health Association have drawn attention to the necessity of more attention being paid to passengers' bedding. Linen must be frequently washed; blankets, mattresses, and pillows aired and exposed to sunshine; dining-rooms should be above the water-line, so as to ensure cleanliness, ventilation, and general wholesomeness, and saloons and smoking-rooms require more frequent ventilation and less heating. Every precaution should be taken to prevent the spread of consumption by dried sputa, spittoons being more freely provided, and charged with some disinfecting solution.

The Infectious Diseases (Notification) Act, 1889.—Both the householder and the medical practitioner are responsible for the notification of each case of infectious disease to the medical officer of health for the district. This applies to any building, ship, boat (English or foreign), any tent, van, shed, or similar structure, whether belonging to His Majesty or not. Penalty, forty shillings. The infectious diseases specified are:—Smallpox, cholera, diphtheria, membranous croup, erysipelas, scarlatina, scarlet fever, typhus, typhoid, enteric, relapsing, continued, or

puerperal fever, and also any infectious disease to which the Act has been applied by the local authority.

The Infectious Diseases (Prevention) Act, 1890, gave increased control over milk supply, enacting that if the medical officer of health is in possession of evidence that any person in the district is suffering from infectious disease attributable to milk supplied to a dairy within or without the district, or that the consumption of milk from such dairy is likely to cause infectious disease to any person residing in the district, such officer shall, after receiving the authority of a Justice for this purpose, have power to inspect the dairy in question, and, if accompanied by a veterinary surgeon, to inspect the animals in it. If on such inspection the medical officer of health is of opinion that infectious disease is caused from consumption of the milk supplied therefrom, he shall report thereon to the local authority, who shall give notice to the dairyman to appear before them, and to show cause why an order should not be made requiring him to discontinue supplying the milk. If in the opinion of the local authority he fails to show such cause, the order may be made, and shall hold good until they are satisfied that the cause of infection has been removed.

Increased powers of disinfection were at the same time given to the officers of the local authority, including the power to remove bedding, etc., for the purpose of disinfection by the local authority at the cost of the latter.

By the same Act, the local authority is required to provide free temporary shelter with the necessary attendance to the members of any family who have been compelled to leave their houses to enable them to be disinfected by the local authority. In 1890 the Public Health Amendment Act consolidated and confirmed many of these powers and since that date defects in the working of the Act as applied to any particular district have been for the most part remedied by private bill legislation in those towns and boroughs which have been before Parliament for general purposes during the last few years.

Secs. 58 to 81 make compulsory the provision of disinfecting apparatus and carriages for carrying infected material, free of charge, by the Sanitary Authority.

Under the Public Health (London) Act, 1891, the Local Government Board in their Memorandum on Ambulances

point out that special regard should be had to the fact that after each use they should be cleaned and disinfected to the satisfaction of a Medical Officer, and in their Rules for Hospitals for Infectious Diseases they further enjoin that the patient's clothes must be disinfected before being given up to him at his discharge.

In the Circular of the Medical Officer (Local Government Board)—issued as a general memorandum on the proceedings which are advisable in places attacked or threatened by epidemic disease,—Section 4 states

"That in the removal of filth during epidemic disease, it is commonly necessary to employ chemical agents for reducing and removing the offence or harm which may be involved in the disturbance of the filth. In the removal of privy contents these agents are more particularly wanted if the disease be cholera or enteric fever. The chemical agent should be used liberally over all exposed surfaces from which filth has been removed. Unpaved earth close to dwellings, if it be sodden with slops or filth, ought to be treated in the same way."

Sec. 5 enjoins "that sources of water supply should be well examined. Water from sources which can in any way be tainted by animal or vegetable refuse, especially those in which there may be any leakage or filtration from sewers, drains, cesspools, or foul ditches, ought no longer to be drunk, above all where the disease is cholera, diarrhœa, or enteric fever. If unfortunately such is the only water to be got for the time, it must be boiled, and then not drunk later than twenty-four hours after boiling. Filtering of the ordinary kind cannot by itself be trusted to purify the water (see p. 18). It cannot be too distinctly understood that dangerous qualities of water are not obviated by the addition of wine or spirits."

Sec. 6 (after remarks about dairies) . . . . "Even apart from any apprehension of milk being concerned in a particular outbreak of disease, it is desirable that English people should adopt the custom, which is always followed in some Continental countries, of boiling all milk at once upon its reception into a house."

Secs. 7 and 8 deal with washing, lime-whiting, overcrowding, and ventilation.

Sec. 9 enjoins cleanliness, rapid removal or destruction of refuse, and avoidance of delay in disinfecting.

Sec. 10 gives "special precautions of cleanliness and disinfection are necessary with regard to infective matters discharged from the bodies of the sick. Among discharges which it is proper to treat as infective are those which come in cases of small-pox and scarlatina from the affected skin; in cases of cholera and enteric fever from the intestinal canal; in enteric fever also the urine; in cases of diphtheria and scarlatina from the nose and throat; likewise, in cases of any eruptive or other epidemic fever, the general exhalations of the sick. The caution which is necessary with regard to such matters must, of course, extend to whatever is imbued with them; care must be taken that bedding, clothing, towels, handkerchiefs, and other articles which have been in use by the sick may not become sources of mischief, either in the house to which they belong or in houses to which they are conveyed. So far as articles of this class can be replaced by rags or things of small value, it is best to use such things and burn them when they are soiled. Otherwise clothing and infected articles should be subjected to the disinfectant of the sick room before washing, or be removed for disinfection by steam heat. In enteric fever and cholera the evacuations should be looked upon as capable of communicating an infectious quantity to any night-soil with which they are mixed in privies, drains, or cesspools, and after such disinfection of them as is practicable they should be disposed of without delay and under the safest conditions the local circumstances permit." (It is quite impossible for this to be done by private effort; the evacuations can only be securely sterilized by heat, and this would involve either a steam apparatus or a dust-destructor. The local authorities must arrange to remove the evacuations daily in sealed iron receptacles, which must be heated for several hours in steam ovens, or steam passed through them, the gases being led into a fire and burnt. A small quantity, about 1 in 500, of phenol, or a cresol preparation (see p. 336) should be added; it has been proved that disinfectants, when hot, act with much more energy than when cold; or mercuric chloride may be used. The residue is then safe).

Sec. 13, in the case of death urges that the body should be placed in a coffin with chlorinated lime and buried or cremated with no longer delay than is necessary.

"Sec. 18. Provision by the public authority for disinfection by heat of bulky articles, and of those which cannot without injury be exposed to chemical agencies, ought always to be in readiness." (Such provision could be associated with the arrangements for the sterilization of excreta described above. Many of the existing apparatus are not large enough.) "Without such provision no complete disinfection can be effected. Partial and nominal disinfection, besides being wasteful, may be mischievous, as giving rise to false security."

Sec. 19. This rule commends a system of domestic disinfection to sanitary authorities "who have already provided adequate public means for the disinfection and for the disposal of infected matters and things." Soiled linen is treated with mercuric chloride solution.

"In places provided with proper systems of excrement disposal, excrements of cholera and enteric fever, after having been treated in detail with the same disinfecting solution (acidified mercuric chloride in ample quantity), may be safely put into the ordinary closet; but special care as to the flushing of drains and sewers, and special frequency in the removal and exchange of excrement receptacles, must be insisted upon. Where the closet is one that communicates with the cesspool or privy pit, the best arrangement for the disposal of infected stools that under these improper local circumstances may be found practicable will have to be adopted." This rule should be re-considered. Klein has proved that mercuric chloride may easily be insufficient even in larger amount than is here recommended (p. 180). The throwing of cholera excreta, even "disinfected" as here described, into closets, to pass thence into rivers and streams, might spread the disease through an entire neighbourhood. Nothing short of the sterilization by heat, as detailed above, is at all certain.

"The interiors of infected rooms should be disinfected by skilled persons acting under the directions of the Medical Officer of Health. The room should be prepared by the removal of such articles as are best disinfected by heat, and of bright metallic objects which would be tarnished; and, where gaseous disinfection is to be employed, by the closing up of all openings and crevices. The gas most frequently employed in the past for the purpose of room-disinfection

has been sulphurous acid gas, obtained by burning sulphur, or liberated from cylinders in which it had been compressed for the purpose; but recent experiments tend to show that the disinfecting power of this agent has been over-rated, and that chlorine gas, which may be obtained by pouring sulphuric or hydrochloric acid upon chlorinated lime, and formic aldehyde gas evolved by means of a special lamp, are more efficacious disinfectants. But, inasmuch as the infection which has to be destroyed is not that in the air of the room, but that clinging as dust and dirt to the surface and recesses of walls, floor, ceiling, and furniture, the use of these gaseous disinfectants may, with advantage, be replaced by the spraying upon the surfaces to be disinfected of a liquid disinfectant such as one or other of the solutions mentioned.

Solutions fitted for the desired purposes are:—

(1) ½ oz. corrosive sublimate, 1 fluid oz. hydrochloric acid, and five grains of commercial aniline blue, in three gallons (a bucketful) of common water. It ought not to cost more than 3d. the bucketful, and should not be further diluted. The use of non-metallic vessels (wooden or earthenware house tubs or buckets) should be enjoined on those who receive it, and articles that have been soaked in it should be set to soak in common water for some hours before they go to the wash.

(2) Chlorinated lime (bleaching powder) in water, of the strength of one part in 100=1lb. to 10 gallons of water.

(3) Formalin—a solution of formic aldehyde gas in water. This may be used diluted in the proportion of 1 part of formalin to 50 parts of water. It is more expensive than the two preceding solutions, but has the advantage of being less corrosive, and less likely to injure articles with which it comes in contact.

After measures of disinfecting a room have been taken, the wall paper (especially if soiled, torn or loose) should be stripped from the walls and be burned, and the room should have its ceilings and walls thoroughly washed or lime whited. The floor and woodwork should also be well washed with soap and water.

Suggestions of the Society of Medical Officers of Health.—Most of these have been previously noticed. The following were the chief points recommended:—

"1. Hang up a sheet outside the door of the sick room, and keep it wet with a quarter of a pint of carbolic acid, No. 4, or a pound of chloride of lime, with a gallon of water. The floor should be sprinkled . . . and the cloths hung up."

"2. Everything that passes from the sick person should be received into ½ pint of green copperas, 1 lb. to the gallon. A like quantity to be added before emptying."

"3. Every sink, closet, or privy should have a quantity of one of the above-named disinfectants poured into it daily, and the greatest care should be taken to prevent the contamination of well or drinking water by any discharges from the sick person."

"4. All cups, glasses, spoons, etc., used by the sick person should be first washed in the above-named solution of carbolic acid, and afterwards in hot water, before being used by any other person." (It would be better to insist that the utensils used by the sick person should not be used by any one else. At the end of the illness they are better destroyed, but if they must be used, they should be boiled for an hour or two with water and washing soda, and then wiped dry. No carbolic acid is then necessary).

"5. All the bed and body linen . . . before being taken from the room, should be first put into a solution of carbolic acid . . ."

6. Prescribes linen garments for nurses, and washing the hands with carbolic soap.

7. Visitors should not be allowed, as their clothing is apt to carry away infection.

"8. The scales and dusty powder which peel from the skin in scarlet fever, and the crust in small-pox, being highly infectious, their escape may be prevented by smearing the body of the sick person all over every day with camphorated oil. This and the after use of warm baths and carbolic soap are most essential. The sick person must not be allowed to mix with the rest of the family until the peeling has entirely ceased and the skin is perfectly smooth; clothes used during the time of illness, or in any way exposed to infection, must not be worn again until they have been properly disinfected."

9. Directions for final disinfection of the room by burning sulphur, and of bedding, etc., by heat. The amount of sulphur prescribed is not sufficient (see page 132).

10. Children from an infected house not to attend school until they obtain a certificate from the medical attendant.

11. In case of death the body should not be removed from the room except to a mortuary; a pound or two of carbolic

powder should be put into the coffin, which should be fastened down and buried without delay. (Cremation is here to be advocated).

In the Army Medical Service (1897 Regulations) special precautions in time of peace enjoin that attendance at schools of children should be stopped and isolation of families secured at the outbreak of any infectious disease. In cholera cases barrack bedding is destroyed, and in cases of itch disinfected, the hospital bedding being made of hair so as to be economically disinfected by moist heat. Kit in infectious cases is destroyed, unless it can be disinfected by moist heat at 220° F. for one hour. Special bed pans are provided for enteric cases which are subsequently disinfected. The following section is important as giving the details of the methods prescribed when an outbreak takes place in quarters:—

(a) The rooms will be vacated, and the windows kept open for as long a time as practicable to insure thorough ventilation.

(b) The furniture, floors, and all painted woodwork will be scrubbed with soap and hot water.

(c) The bedding and clothing in use will be disinfected, except those in use by patients suffering from small-pox or cholera, which will be destroyed. Carpets, curtains, etc., will be removed into the outer air, carefully beaten, brushed, and exposed to the air and sun for at least three days.

(d) The ceilings will be whitewashed.

(e) The walls, if papered, will be re-papered, the old paper being first carefully scraped off. If not papered, they will be scraped or broomed down as may be considered necessary and finished as before. The re-papering will be restricted to the room in which the case shall have occurred.

When considered advisable, the room in which the case occurred will be vacated, thoroughly cleaned and limewashed, and left unoccupied, with the windows open as long as practicable; when, in addition, it is deemed necessary to fumigate the room, the instructions given later will be followed.

In barracks, bedding used by a person suffering from any infectious disease prior to admission to hospital will be burnt unless the coir can be economically disinfected by moist heat; and the bedding, with all clothing, which, in the opinion of the medical officer in charge of the case, has been exposed to infection, will be disinfected. All soiled bedding and under-clothing which has been in intimate contact with the sick will be immediately steeped in corrosive sublimate solution, and subsequently boiled and washed without removal to hospital for further disinfection. Such articles as are Government property will be handed over, after steeping in corrosive sublimate solution,

to the officer in charge of barracks for the purpose of being boiled and washed, except in cases of cholera or small-pox, when they will be destroyed. Such articles of clothing as cannot be steeped, boiled, and washed will be disinfected by moist heat.

Special precautions are adopted for hospital bedding and in cases of venereal disease.

It is also pointed out that in stations where no proper disinfecting apparatus by moist heat is provided, local arrangements will be made with the civil sanitary authorities to have infected clothing disinfected by moist heat; and that in some instances the plan of exposing articles of clothing to the air and sun for a week, and subsequently beating and brushing them, may be adopted, but in no case may this procedure be considered as a sufficient alternative for proper disinfection by moist heat.

In 1897 the following disinfectants were used in Military stations :—

Carbolic acid.
Chloride of lime.
Corrosive sublimate.
Izal (for use in hospitals only).
Quicklime.
Sulphate of iron.

The following standard solutions of the above disinfectants were recommended :—

(a) Carbolic Acid.

This disinfectant will be mainly employed for the disinfection of tuberculous sputum. It may be also employed with advantage for disinfecting cholera dejecta. If available in the crystal form a 5 per cent. solution should be used. The crude commercial form is weaker, and needs to be employed in much larger quantities.

(b) Chloride of Lime.

Dissolve 4 ounces of chloride of lime in 1 gallon of soft water. Use 1 pint of this solution for disinfection of the excreta in cholera, enteric fever, etc. All discharges should be left in contact with this disinfectant for ten minutes before final disposal.

(c) Corrosive Sublimate.

This may be accepted as the most reliable disinfecting agent. The following solutions should be used :—

Corrosive sublimate	½ an ounce
Hydrochloric acid	1 ounce
Water	3 gallons

This solution may be taken to be of a strength of 1 in 1,000, and should be tinted either with a sufficiency of permanganate of potash or aniline blue, so as to make it of a distinctive colour.

(d) Izal.

This may be used as a liquid disinfectant for excreta, etc. It

is best employed as a watery solution of not less strength than five per cent. Its action is somewhat slow, and it should remain at least half-an-hour in contact with the object to be disinfected. It constitutes an excellent disinfectant for ward utensils.

(e) Quicklime.

This is applicable for use on a large scale, when there is a considerable space and bulk of material to deal with. After midden heaps and foul channels, etc., have been emptied, quicklime may be freely sprinkled over them.

(f) Sulphate of Iron.

This has distinct germicidal and antiseptic qualities. It should be employed in the form of a 10 per cent. solution for the disinfection of dejecta, the same being exposed to its action for at least one hour.

When fumigation of an ordinary room is considered necessary compressed sulphur dioxide in cylinders will be employed.

One of the 20 oz. cylinders may be considered to be suitable for rooms of about 12 feet cube, or roughly 1,700 cubic feet.

The room to be disinfected should be sealed up in the usual manner, only the doorway being left open, by which the operator is to make his exit, and that doorway being left ready for immediate sealing up.

The cylinder of the compressed gas must be taken in the left hand, pointing away from the operator, who, cutting off the soft lead vent pipe by one stroke of a strong knife, must at once place the cylinder in a washbasin with the outlet inclined downwards so that the liquid may flow out, the liquid gas will evaporate in about a quarter of an hour. The operator should at once escape from the room and seal up the doorway or other aperture of exit.

At the end of eight hours, the room should be re-opened, and the sulphurous gas allowed to escape.

In cases where the fumigation of a mortuary is deemed necessary, preference may be given to the use of chlorine gas, which effectually destroys the odours peculiar to such places. Chlorine gas may be conveniently generated in the following manner; the quantities here given being sufficient for 1,000 cubic feet and space:—

Chlorine.

Common salt	8 ounces
Oxide of manganese (in powder)	2 ,,
Sulphuric acid	4 ,,
Water	4 ,,

The water and acid to be mixed together, and then poured over the other ingredients in a delf basin, which should be placed in a pipkin of hot sand. Owing to the specific weight of this gas it is necessary to suspend the vessel in which it is generated as close to the ceiling as possible.

Metropolitan Asylums Board.—The disinfection of ambulance carriages and steamers used to be done by washing with carbolic acid.

The hospital linen is soaked in carbolic solution, and then boiled and washed (it requires not less than 1 in 20 carbolic to disinfect linen; the solutions usually employed are not as strong as this—*e.g.*, the one recommended by the Society of Medical Officers of Health (p. 205) is only $\frac{1}{4}$ pint to a gallon, or 1 in 32. This means that carbolic disinfection as commonly carried out is imperfect. In the new hospitals clothing is disinfected by steam).

SYSTEMS IN OTHER COUNTRIES.

Space will not allow us to describe the regulations for disinfection that are now in force in most countries, but a few of the more recent may be noticed.

France. The Public Health Law of 15th February, 1902, declares that declaration and disinfection are obligatory in all cases of typhoid, typhus, smallpox, scarlatina, measles, diphtheria, miliary fever, cholera, plague, yellow fever, dysentery, "puerperal fever and ophthalmia of infants when the birth has been concealed," epidemic meningitis. In a second list, including pulmonary tuberculosis, whooping cough, influenza, pneumonia, erysipelas, mumps, leprosy, thrush, and purulent ophthalmic affections, declaration is voluntary ("facultative") and disinfection is encouraged. Rules are imposed as to isolation, disinfection of fabrics and utensils, and disposal of excreta. The final certificates of disinfection are to mention the place, but not the name of the patient nor the nature of the malady. Immersion of linen in boiling water for a quarter of an hour is recommended. Processes of disinfection shall be approved by the Minister of the Interior advised by the Committee of Public Hygiene, and a decree of March 7th, 1903, arranges for the examination and control of apparatus for the purpose, which must not be used unless an official certificate of efficiency is shown. The list of bacterial tests to be applied includes dried tuberculous sputa, B. diphtheriæ, typhosus, anthracis, subtilis and S. pyog. aureus, disposed in mattresses, on paper, in envelopes, and in cracks and holes in blocks of wood. The Inspector-General, Dr. Martin, mentions that, besides seven different types of stoves in which formaldehyde is an adjunct, 27 varieties of apparatus for the use of this

substance have been examined. The majority gave about equivalent results provided at least 2·5 grammes of formaldehyde per metre cube (= 71 grms. per 1,000 cub. ft., see p. 318) were evaporated, with a minimum contact of 7 hours. For testing stoves, a special design of self-registering thermometer is used, with the bulb enclosed in a kind of small muff made of wadding covered with mattress-material, so as to attain constant conditions as to heat penetration. It is required that a thermometer placed at any point in the chamber, with the bulb encased in a muff six inches thick, should show a satisfactory curve, rising above a certain temperature in a time relatively short.

Spain. In the "General Instruction on Public Health," passed on July 14th, 1903, the list of diseases in which declaration and disinfection is *obligatory* goes further than the French one just quoted, as it includes whooping cough, influenza and tuberculosis. The regulations are much as in France. The owner is to be compensated for destruction or damage occurring in compulsory disinfections. In the syllabus of methods prescribed the following points should be amended. (1) Variation of treatment according to the population may be sometimes unavoidable but is carried too far, as contrasted with the advantage of a uniform system. (2) There seems undue dependence on milk of lime. (3) Phenol and creolin are prescribed in the same strength—5 per cent., indiscriminately with 2 to 5 per cent. sulphate of copper. (4) In boiling linen it is directed to add to the water 6 to 25 grammes *per litre* of common salt, "not as a disinfectant, but solely to raise the boiling point." But saturation with salt (350 grammes per litre) only raises the B.P. 9° C., so that these small quantities could have little effect. Pressure steam, formalin vapour, and SO_2 are approved in this order, and mercuric chloride 1 in 1000 for spraying. Chloride of lime is only mentioned for optionally strengthening milk of lime.

Belgium. An example of the Municipal administration is given in the illustrated report of the Bureau d' Hygiene, Antwerp, 1903. Disinfection of rooms is practised with the Roberge formaldehyde apparatus, a tubular heater with Primus petroleum lamp. For clothes there are five stoves, working with pressure steam at 135° C. Soapy solutions of cresol are used for spraying.

CHAPTER XVI.

METHODS OF ANALYSIS.

(A.) Bacteriological Methods: Conditions to avoid error—Determination of the Antiseptic Value—I. Of Antiseptics in Solution—Wynter Blyth's Method for Sewage Antiseptics—Precautions necessary in these Tests—II. Of the Vapours of Volatile Liquids—Chamberland and Klein's Methods—III. Of Gaseous Antiseptics. Determination of the Germicidal Value: Relative Value of the Culture and Inoculation Tests—Examination of Disinfectants in Solution—Dilution Methods of Sternberg and Wynter Blyth—Thread Methods—Examination of Gases and Vapours—Fischer and Proskauer's Apparatus. Standardization of Disinfectants. (B.) Chemical Methods: Necessity of Analysis—Requirements. Chloride of Lime: Preparation of Standard Solutions and Titration. Sulphurous Acid and Sulphites. Peroxide of Hydrogen. Boric Acid. Metals. Permanganate. Phenol: Estimation of Water—Of Phenol by Bromine—Of Cresol—Examination of Tar Oils—Carbolic Powders—Hager's Glycerine Test—Carbolic Soaps—Salicylic Acid and other Preservatives in Foods—Tests for Thymol, Naphthol, etc.—Medicated Wools.—Tests of Penetration,

In order to estimate the antiseptic or disinfectant value of a given substance it is necessary to examine its effect upon known organisms under known conditions. In dealing with commercial products it is always desirable to ascertain their chemical composition and the relative amount of the active ingredients present. A full analysis is in many cases of value, since there is abundant evidence that when an active substance is mixed with others the germicidal value of the mixture is modified, as shown by exceptional results which have been obtained when two or more chemical substances have been used together. The probable explanation is the selective affinity which different micro-organisms exhibit towards different chemical compounds, so that, in addition to the cumulative power of the several constituents present, there is a further toxic effect produced by their individual action.

(A.) Bacteriological Methods.

The principles underlying the methods employed are of extreme simplicity, but the conditions under which the determinations of efficiency are made have a great influence on the results. Unfortunately sufficient care has not in the

past been taken to specify the conditions of experiment with exactness, nor has it been recognized that the relative values given for the efficiency of antiseptics and germicides are only to be accepted for the given experimental conditions. While the processes have had general resemblance, they have varied infinitely in details, so that the results obtained by different observers are very rarely strictly comparable. The danger of neglecting the conditions is especially evident when attempts are made to apply certain experimental results to the actual practice of disinfection. We shall indicate later a general system of testing proposed for the standardization of these products.

The earliest investigations were chiefly directed to ascertain the antiseptic value in putrescible animal and vegetable infusions, previously sterilized by boiling, by observing the dose necessary to prevent putrefaction, or the period during which putrefaction was averted. The liquids were exposed to the air and compared with similar untreated samples. Beef-broth, milk, urine, infusions of hay and turnip, or pastes made of bread, potato, etc., were used, and the occurrence of smell and turbidity was taken as index of the limit of action of the antiseptic. The converse experiment, which was a crude attempt to determine the germicidal value, was also employed. A fluid in which putrefaction was already well established was treated with the antiseptic in known proportions for a fixed time, and drops of the putrescent fluid were then used to infect fresh sterile, but putrescible, media. If these materials decomposed it was evidence that the antiseptic had failed to sterilize the original fluid. The errors involved in these methods are—

(1) The use of an unknown mixture of micro-organisms, whereas it has been shown that an antiseptic has very varying effects on different species. (2) The presence or absence of spores in the inoculating mixture was rarely observed. (3) When the inoculation is left to aërial contamination the infection is by no means uniform. (4) The infecting mixture may not be identical in the experimental and control media. (5) Odour and turbidity cannot always be relied upon to indicate the first occurrence of microbic growth. (6) In conducting experiments in which the already putrescent fluid is used to inoculate fresh media it is impossible, since it is not known what varieties of organisms are present in the

inoculating fluid, to be sure whether the secondary growths are caused by the inoculation or are the result of accidental contamination. Koch, in his classical researches on the value of antiseptics, pointed out these objections, and insisted that the experiments should be made with pure cultures of microbes, whose condition as to spore formation was accurately known and which could be used to artificially inoculate the test fluids with a known organism. Many pitfalls have since been discovered, but accurate experimental work dates from these researches.

The bacteriological examination of antiseptics and disinfectants is directed to ascertain—

(1) What retarding or inhibitory influence the agent exercises on the growth of a specific micro-organism—*i.e.*, what is its *antiseptic* power. (2) What effect it has in diminishing the virulence of pathogenic germs. (3) In what dose and in what time it will cause the death of the microbe; what is its *germicidal* value. Modifications of virulence under the action of antiseptics, though most important, have only been determined in the case of a small number of micro-organisms. For practical purposes the desirable end is to cause the death of the infective agent, not simply to modify it. The experimental methods vary according to the physical condition of the disinfectant, whether it is employed as a solution or as a gas, and although solid antiseptics are employed it is only after solution that they are effective. The relative efficiency of antiseptics and disinfectants is expressed in terms of the dose and the time of action required to produce a given effect.

Determination of the Antiseptic Value.

I. Examination of Antiseptics in Solution.—(*a*) A series of flasks or test-tubes containing suitable culture fluids is prepared. To certain of these flasks known quantities of the antiseptic to be tested are added, while others are left as control flasks. After sterilization the flasks are inoculated with the test organism and placed under suitable and similar conditions of temperature, aëration, etc. If the maximum antiseptic power is to be measured, then the conditions under which the flasks are placed must be those most favourable to the growth of the organism. As the only variable factor in the two series of flasks is the presence or absence

of the antiseptic, any retardation or inhibition of growth must be due to this variant. The occurrence of growth is determined by changes in the appearance of the media and by microscopic examination. (*b*) Wynter Blyth[1] suggested a method, intended chiefly to gauge the value of an antiseptic for sewage purification, in which the proportion of microbes remaining alive after a given time of action of the antiseptic is estimated by culture and enumeration of colonies. Sewage or sewage-contaminated water is treated with a known proportion of the antiseptic, and at varying periods known volumes of the mixture are withdrawn and inoculated into definite volumes of the liquefied gelatine medium. After thorough mixing, plate cultures are made in Petri capsules. The capsules are placed under suitable conditions, and the number of colonies which develop are counted. If parallel experiments are made with two or more antiseptics the relative efficiency is in inverse proportion to the number of colonies found in the cultures. In this method it is assumed that the number of organisms inoculated is approximately equal. The plan has the usual disadvantages attaching to the gelatine plate method.

Precautions.—If the antiseptic is volatile the culture fluids must be first sterilized by heat, and then the antiseptic added by means of a sterilized pipette. It must not be assumed that because growth does not appear so readily in the flasks containing the antiseptic as in the control, that therefore the proportion of antiseptic is sufficient to arrest growth. The flask should be kept for not less than two weeks (*Sternberg*), as after long periods of retardation the restraining power often breaks down and copious growth takes place. The principal factors which cause variations in the efficiency of the antiseptics are—

(1) *Change in the Microbes experimented with.*—Certain microbes have a peculiar tolerance towards certain antiseptics—*e.g.*, *B. typhosus* and iodine trichloride. Others are much affected by the acidity or alkalinity of the medium, and the change in reaction due to the added antiseptic may be the cause of variation.

(2) *Change in the Medium.*—A diminution in the nutritive value of the medium will apparently increase the

[1] *Proc. Roy. Soc.*, 1886.

antiseptic power. The chief effect of change of medium is, however, due to changes which occur in the chemical reactions between the antiseptic and the constituents of the medium. All antiseptics which form precipitates with albumens have their efficiency diminished when an albuminous fluid is employed—*e.g.*, $HgCl_2$, $AgNO_3$, etc.; and, similarly, any substance which by precipitation diminishes the available amount of soluble antiseptic present—*e.g.*, NaCl with $AgNO_3$, or H_2S with $HgCl_2$—will greatly diminish the apparent activity of the agent.

(3) *Change of Temperature.*—This factor acts in two opposite directions. An increase in temperature up to the *optimum* temperature of growth of the microbe is favourable to the micro-organism, but the rise of temperature also increases the activity of the antiseptic. Which factor will prove most active can only be determined experimentally.

II. Examination of the Vapours of Volatile Fluids.—The principle of the methods employed is similar to that described for solutions.

(*a*) *Chamberland's Method.*—A U-tube similar to those used for anaerobic cultures is employed. Into one limb the volatile fluid is aspirated, into the other the inoculated culture medium. The tubes are then sealed. The space above the fluid becomes saturated with the antiseptic vapour. The occurrence of growth is determined as before.

(*b*) *Klein's Method.*[2]—Short and wide tubes are prepared containing sterile agar medium with the usual sloping surface. The volatile antiseptic is placed on the side of the tube opposite the agar, and the excess runs to the bottom of the tube. The agar is then inoculated in its upper part, well away from the fluid and the tubes, tightly plugged and, if necessary, capped with an india-rubber cover, and kept at a suitable temperature. The efficiency of the antiseptic is evidenced by the absence of growth.

III. Examination of Gaseous Antiseptics.—The methods will be described when dealing with the germicidal value of disinfectants.

Determination of the Germicidal Value.

Principle of the Methods.—The disinfectant is allowed to act for a known time in a known strength on a pure

[1] *Ann. Inst. Pasteur*, vol. i., p. 163. [2] *Brit. Med. Journ.*, 1894, vol. i., p 375.

culture of a micro-organism. The disinfectant is then removed, and the death or continued vitality of the organism determined by (1) the capacity to produce fresh cultures, or (2) the power to produce a pathogenic effect when inoculated into susceptible animals. The objects to be attained are:—(1) The perfect exposure of the organisms to the action of the disinfectant. In order to ensure this condition the organisms should be in suspension or exposed in a very thin layer, and care should also be taken that the microbes are not coated with any layer, such as oil, which would mechanically prevent the action of the disinfectant. (2) The perfect removal of the disinfectant from the organisms whose vitality is to be tested. The various modifications in the experimental methods are chiefly directed to this end. Geppert has shown the great difficulty that there is in freeing the organisms from adherent material, and also the enormous influence that infinitesimal doses of disinfectant may have in retarding or hindering growth. This is especially marked with regard to the germination of spores. Geppert experimented with anthrax spores and mercuric chloride, and demonstrated the different results obtained according as the mercuric chloride was simply washed away or removed by precipitation with ammonium sulphide. He also showed that the amount of mercuric chloride required to prevent the development of spores which had been exposed to the action of the disinfectant was very much less (only 1 : 2,000,000) than the proportion required to produce the same effect on spores which had not been so exposed, and that the longer the exposure the less was the amount required.

Relative Value of the Culture and Inoculation Tests in the Determination of the Vitality of the Disinfected Organisms.—Opinions differ very considerably on this point. There can be little doubt that for the determination of the continued vitality of the organism the culture test is the more delicate, and for this reason, as well as for the considerations of economy and convenience, it is the one usually employed. For determining alterations in the virulence of the microbes, the inoculation test is the only one available. The great objection to the animal inoculation test is the fact that exposure to the disinfectant so modifies the virulence of the organisms that they no longer produce their pathogenic effect, though they retain their vitality. There

is no certainty that these non-virulent organisms may not give rise on germination to virulent growths, and therefore, for practical purposes, the death rather than the alteration of the organisms is to be desired. An animal which has been used for an inoculation test cannot be employed a second time, even if it has apparently not suffered any ill effects, as a condition of insusceptibility, a vaccination, may have been produced by the first inoculation.

Examination of Disinfectants in Solution.—*Dilution Methods.*—There are several methods, varying in detail, in which, after exposure of the organisms to the action of the disinfectant, a small portion of the culture is removed and inoculated into a relatively large volume of a nutrient medium. The dilution thus brought about is trusted to reduce the amount of the disinfectant carried over below the amount which would cause inhibition of the growth. If thought advisable, a second inoculation, with consequent further dilution, may be made from a primarily infected culture. It is obviously important that fluid media should be used for the culture test, or otherwise the removal of the disinfectant is not secured.

(*a*) *Sternberg's Method.* A known volume (5 c.c.) of the standardized disinfectant is added to an equal volume of fluid (bouillon) culture of the micro-organism. After exposure for a given time a small portion of the mixed culture is withdrawn and inoculated into a suitable culture medium. The results are calculated as produced by a disinfectant of one half the strength of the solution added to the culture. Either the time of exposure or the strength of the solution can be made the variable factor.

(*b*) *The Drop Method (Wynter Blyth).*—Sterilized distilled water is infected with the test organism, and measured volumes of the infected water are added to known volumes of the disinfectant. After a given time a drop of the mixture is added to 10 to 20 grammes of liquefied gelatine medium, and the growth watched. Bouillon is a more suitable medium, as many pathogenic germs grow slowly at temperatures at which gelatine remains solid and retains its distinctive advantages. Bouillon has also been shown in Miquel's experiments to give greater opportunity for the growth of organisms whose vitality has been reduced than the solid media. If it is desired to use micro-organisms from

cultures in solid media, the growth is scraped off with a wire and suspended in sterile distilled water. Such suspensions, filtered to remove flocculi, are employed advantageously, because the disturbing effects of varying media and the presence of precipitates are avoided.

(*c*) *The Thread Method.*—This is often known as *Koch's method,* as it was employed by him in examining the action of antiseptics on the spores of Bacillus anthracis. Sterilized silk threads were soaked in cultures containing anthrax spores (or, better, suspensions of spores in sterile water) and dried. The threads were allowed to hang in the disinfectant for the desired time and afterwards withdrawn, washed in sterile water, and inoculated either into animals or fresh nutrient media. Koch employed solid media for his inoculations. This method has been much used, and possesses the advantage that the disinfectant can be got rid of by washing. If fluid media are employed for the test cultures it possesses also the advantages of the dilution methods. When employed for non-spore-bearing organisms the intermediate drying should be omitted, as that itself will diminish the vitality of many organisms in the vegetative form. Suspensions in sterile water are preferable to fluid cultures in which to soak the threads, as the (often albuminoid) medium forms a coating when dry which protects the organisms. In all cases control experiments must be made in which threads are treated, just as are the test threads, except that sterile water is substituted for the disinfectant. Instead of threads platinum wires have been employed, and Blyth has suggested the use of small plugs of sterilized cotton wool attached to capillary glass rods by means of sealing wax. There must be some difficulty in securing efficient sterilization of these mops.[1]

(*d*) *The Garnet Method.*—This was introduced by Krönig and Paul[2] and consists in first coating the surface of small garnets with an aqueous culture of the bacteria under examination, which are then dried at a low temperature over calcium chloride. The garnets should be of uniform size and when coated in this way can be introduced into the disinfectant solution for a known time at a given temperature. After medication they can be removed from the

[1] See also the Author's comments on the thread method in the *Lancet,* July 30th, 1900

[2] *Zeits. f. Angewandte Chem.*, 1901, Heft. 14 and 15.

disinfectant, washed with water or even heated with chemical re-agents to neutralize any adhering disinfectant, and transferred to tubes containing sterile water. These tubes are violently shaken so as to detach the bacteria from the surfaces of the garnets and the water added to agar or gelatine in Petri dishes and incubated in the ordinary way. These authors consider it desirable to count the number of organisms which survive this treatment, and do not determine sterility or otherwise by simply incubating in liquid media as is commonly practised.

Examination of Gases and Vapours.—The method of Chamberland described above is equally convenient for the determination of the germicidal action of the vapour of essences, volatile oils, etc. Instead of an inoculated medium, a suspension of a given microbe is aspirated into one limb of the tube, and after exposure for the desired time a drop of the culture is withdrawn for inoculation. It must be remembered that unless the gas or vapour is soluble in water only the surface is exposed to the action of the disinfectant. When it is not required that the proportion of a gaseous disinfectant present should be known, or when the effect of a saturated atmosphere is to be tested, the micro-organisms, either on threads, or in very thin layers on sterile cover glasses, or on sterile filter paper which has been dipped into cultures or water suspensions and allowed to dry, may be exposed under a bell jar to the action of vapour evolved from a capsule of the volatile disinfectant also placed under the jar. Test-tubes with bulbous ends, such as are used for potato cultures, may also be conveniently employed, the disinfectant being placed in the bulb. The threads, cover glasses, etc., are used to inoculate culture media either directly or after washing.

Fischer and Proskauer's Method.[1]—These two observers made a series of very complete investigations on the action of several gaseous disinfectants, including sulphurous acid and the halogens. Their apparatus consisted of a 20-litre very wide-mouthed jar, through whose stopper tubes for the delivery and exit of gas were passed. Both tubes were provided with taps, and the exit tube was furnished with a series of absorption bulbs. A thermometer also passed through the stopper. The centre of the stopper was itself

[1] *Mitt. aus dem K. Gesund.*, Bd. II., 1884.

perforated and fitted with a large india-rubber cork, through which passed a glass rod, carrying a series of glass shelves in which the objects to be disinfected could be placed. Such an apparatus permits of the exposure of test objects to the action of the disinfecting gas under the most diverse conditions, and also allows the amount of the gas present in the apparatus to be determined.

Most of the conditions which affect the determinations of antiseptic and germicidal values have been already considered, but there is one factor which is not under experimental control, and which imparts an element of uncertainty into the results. This factor is the variation in vitality and resistance of different specimens of the same micro-organism. In any culture there is a rather wide range of variability in the individual organisms, and this range of variability is increased if the cultures are not of the same age and grown under the same conditions on the same medium. The age and nature of the culture should always be specified, and this element of variability eliminated so far as possible by multiplying the experiments. It is obvious that the methods detailed above must be varied as the problems to be solved differ; but the principles to be kept in view, and which have been insisted upon, are constant; while the errors to be avoided are also very similar in every investigation.

In England there exists no official control over the sale of disinfectants, with the exceptions of those set forth in the Privy Council Orders of July 27th, 1900, and June 5th, 1902. The first of these permits the sale, without control, of liquids containing less than 3 per cent. of carbolic acid or its homologues, as disinfectants, on the ground that such fluid is not a poison within the meaning of the Pharmacy Act of 1868, and this has the direct effect, obviously, of placing a premium on inefficiency. In the subsequent order it is stated, liquid disinfectants containing scheduled poisons (which for present purposes are practically confined to carbolic acid and its homologues in solutions of more than 3 per cent., and corrosive sublimate) shall be sent out in bottles rendered distinguishable by touch from ordinary medicine bottles, with a label giving notice that the contents of the bottle are not to be taken internally. Formaldehyde, and presumably potassium mercuric iodide, which are both

efficient disinfectants, can be advertised and sold as such by anyone without control.[1]

It has been frequently suggested that the provisions of the Food and Drugs Act should be extended to such articles as in other countries (*e.g.*, Massachusetts, U.S.A.) such legislation exists.

The absence of a thoroughly reliable test may in a great measure account for this apparent apathy on the part of the authorities. It is obvious that a bacterial, rather than a chemical determination of efficiency is required, as although the strength of a preparation of carbolic acid and its homologues can be ascertained with great accuracy, it is a well-known fact that creolin, for example, does not depend for its remarkable efficiency as a bactericide on the content of these acids. Again, much depends upon the conditions, both chemical and physical, in which the disinfectant is employed. Thus a disinfectant containing 10 per cent. of tricresol *in emulsion* is equivalent in bactericidal value to one containing 30 per cent. *in solution,* when tested against a virulent culture of B. typhosus.

A standard method for the examination of disinfectants should include a consideration of the following factors:—

1st.—Time.
2nd.—Age of Culture.
3rd.—Choice of Medium. Reaction of same.
4th.—Temperature of Incubation.
5th.—Temperature of Medication.
6th.—Variations in vital resistance of same species.
7th.—Variations in vital resistance of different species.
8th.—Proportion of culture to disinfectant.

The author, in conjunction with Mr. Anislie Walker, has suggested that pure phenol should be adopted as a control standard.[2] The so-called pure crystals contain at times as much as 7 or 8 per cent. of water, but if the operation of standardizing a solution by means of bromine be considered too tedious, the B. P. article will be found to answer the purpose admirably. 110 parts by weight of B. P. carbolic acid contain 100 parts by weight of pure phenol. In many

[1] Biniodide of mercury has been added to the schedule of poisons in Ireland, but not in England.

[2] *Journ. San. Instit.*, 1903.

respects this disinfectant has marked advantages over a metallic salt or other standard.

The method proposed may be described briefly as follows: To 5 c.c. of a particular dilution of the disinfectant in sterilized water add 5 drops of a 24 hours' blood-heat culture of the organism in broth; shake and take sub-cultures every $2\frac{1}{2}$ minutes up to 15 minutes. Incubate these sub-cultures for at least 48 hours at 37° C. Allowing 30 seconds for each act of medication and the same time for making each sub-culture, four different dilutions of the disinfectant under examination, together with one standard control, may be tested against the same culture, under conditions which make the results strictly comparable. If preferred, the field may be extended and divided into intervals of 5 minutes: but we contend that no table is complete which does not show a positive result in the first column, and a negative result in the last. The strength or efficiency of the disinfectant is expressed in multiples of carbolic acid performing the same work:—*i.e.*, when a dilution of the disinfectant is obtained which does the same work as the standard carbolic acid dilution, the former is divided by the latter, and a ratio termed the "carbolic acid co-efficient" is thus found.

The following table shows the degree of refinement to which this test may be carried with a little care:—

TABLE I.—*B. Typhosus (Kral) 24 hours' Broth Culture at 37° C.*

Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		$2\frac{1}{2}$	5	$7\frac{1}{2}$	10	$12\frac{1}{2}$	15	Period of Incubation.	Temperature.
Disinfectant W...	1 : 70	×	×	.	.	.	.	48 hours	37° C.
,, ...	1 : 80	×	×	×	.	.	.	,,	,,
,, ...	1 : 90	×	×	×	×	×	.	,,	,,
,, ...	1 : 100	×	×	×	×	×	×	,,	,,
Carbolic Acid ...	1 : 80	×	×	.	.	.	.	,,	,,

Carbolic Acid Co-efficient $\frac{70}{80} = 0.87$.

We are now in a position to discuss the influence of the various factors enumerated.

1st. *Time.*—One of the greatest mistakes made in estimating the relative values of disinfectants is introduced

in taking *strength of disinfectant* as the constant and *time* as the variant. A glance at tables II. and IIA. will convey some idea of the extent of the error due to the adoption of this method. It is therefore evident that to obtain regular and consistent results, time must be taken as the constant and strength as the variant.

TABLE II.—*B. Coli, 24 hours' Broth Culture at 37° C.*

Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Disinfectant No. 1 (containing 19·5% Cresols) ...	1 : 200	×	×	.	.	.	.	48 hours	37° C.
Disinfectant No. 2 (containing 10·1% Cresols) ...	1 : 100	×	×	.	.	.	.	,,	,,

True relative values = 2 : 1.

TABLE IIA.—*B. Coli, 24 hours' Broth Culture at 37° C.*

Room Temperature 15°—18° C.

Sample		Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Disinfectant No. 1 (containing 19·9 % Cresols) ...	1 : 200	×	.	.	.	.	.	48 hours	37° C.
Disinfectant No. 2 (containing 10.1 % Cresols) ...	1 : 200	×	×	×	×	×	.	,,	,,

Apparent relative values = 11 : 1.

2nd. *Age of Culture.*—This is a factor which is often ignored. In the usual trial with a non-sporing organism where a primary culture in nutrient broth is prepared and small quantities are mixed with the diluted disinfectant, a variation in the incubation period undergone by the primary

culture will make a difference in the valuation of the disinfectant. As an example of this we have prepared a culture of B. typhosus in nutrient broth incubated at 37·5° C. After 16 hours' incubation 0·1 c.c. of this culture was removed with a sterile pipette and added to 3 c.c. of diluted disinfectant fluid. The remainder of the primary culture was then incubated for a further 8 hours; 0·1 c.c. was then removed and treated with the disinfectant as before, and this was again repeated after a further incubation of 16 hours. The actual number of typhoid organisms present in the culture was carefully determined at the end of each period. The results were as follows:—

TABLE III.—*B. Typhosus, Broth Cultures at 37·5° C.*

Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Period of Incubation. Primary culture.	No. of Organisms per c.c. after 48 hours incubtn.	Temp.
		2½	5	7½	10	12½	15			
									millions	
Disinfectant A	1 : 95	×	×	×	.	.	.	16 hrs.	212	37 5°C.
,,	,,	×	×	×	.	.	.	24 ,,	233	,,
,,	,,	×	×	×	×	×	×	48 ,,	90	,,

These results are also of interest in showing that the resistance of a culture to the action of a disinfectant is by no means dependent on the actual *number* of organisms present. In the above instance the typhoid had reached its maximum degree of multiplication apparently after 16 to 24 hours, and with a further incubation at the optimum temperature the number of organisms diminished; their power of resistance to the action of the disinfectant was, however, decidedly increased. The explanation of this result may be found in the slight clotting of the culture which takes place during protracted incubation. The bacilli in this way appear to be to a great extent protected from the action of the disinfectant by each other, and by their own products. But no false or misleading results can be obtained with an attenuated culture, either by design or through ignorance, where a carbolic acid control is introduced (*cf.* Tables IIIA. and IIIB.).

TABLE IIIA.—*B. Typhosus, 24 hours' Broth Culture at 37° C.*

Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Fluid W¹.....	1 : 90	.	.	.	.	.	.	48 hours	37° C.
,, ,, ...	1 : 100	×	.	.	.	.	.	,,	,,
Carbolic Acid.....	1 : 90	.	.	.	.	.	.	,,	,,
,, ,, ...	1 : 100	×	.	.	.	.	.	,,	,,
,, ,, ...	1 : 110	×	×	×		.	.	,,	,,

Carbolic Acid Co-efficient = 1·0.

TABLE IIIB.—*B. Typhosus, 48 hours' Broth Culture at 37° C.*

Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Fluid W¹.....	1 : 90	×	.	.	.	.	.	48 hours	37° C
,, ,, ...	1 : 100	×	×	×	.	.	.	,,	,,
Carbolic Acid	1 : 90	.	.	.	.	.	.	,,	,,
,, ,, ...	1 : 100	×	×	×	.	.	.	,,	,,
,, ,, ...	1 : 110	×	×	×	×	×	×	,,	,,

Carbolic Acid Co-efficient = 1·0.

3rd. *Choice of medium: Reaction of same.*—For most practical purposes the choice of media is restricted to broth and agar. The behaviour of cultures of B. coli obtained from both is shown in the following tables:—

TABLE IV.—*B. Coli, 24 hours' Broth Culture at 37° C.*

Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Disinfectant A ...	1 : 1000	×	×	.	.	.	.	48 hours	37° C
Disinfectant Z ...	1 : 800	×	×	.	.	.	.	,,	,,
Carbolic Acid.....	1 : 100	×	×	.	.	.	.	,,	,,

Co-efficients { A = 10·0. Z = 8·0.

TABLE IVA.—*B. Coli, 24 hours' Agar Culture at 37° C.*

Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Disinfectant A ...	1 : 1500	×	×	.	.	.	.	48 hours	37° C
Disinfectant Z ...	1 : 1200	×	×	.	.	.	.	,,	,,
Carbolic Acid ...	1 : 120	×	×	.	.	.	.	,,	,,

Co-efficients { A = 12·5. Z = 10 0.

In both cases the higher factor is obtained when using agar cultures, which are prepared by taking up part of the growth on the point of a needle and distributing it evenly in sterilized water; the resulting emulsion may be used in the place of the broth culture, but we recommend the latter as being much more convenient to handle.

The reaction of the medium used for primary cultures is a factor of greater interest.

TABLE IVB.—*B. Typhosus, 24 hours' Broth Culture at 37° C.*

Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Carbolic Acid[1] ...	1 : 90	×	×	.	.	.	.	48 hours	37° C.
Carbolic Acid[2] ...	1 : 120	×	×	.	.	.	.	,,	,,

[1] Culture grown in Broth, acid to phenolphthalein 100 c.c. = 0·6 Normal NaHo.
[2] ,, ,, alkaline ,, 100 c.c. = 0·2 Normal HCl.
N.B —Both were alkaline to Litmus paper.

These media corresponded therefore to reactions of +0·6 −0·2 respectively. The American Public Health Association in 1898 adopted a reaction of +1·5 per cent. as the best for general work, and this has been adopted in these tests.

The fresh meat recommended in many of the text books might be replaced by Liebig's extract, to the greater

convenience of the operator; but the *reaction* of the resulting broth is a detail which will not admit of any latitude.

4th. *Temperature of incubation.*—The extent to which this factor will affect the power of resistance of a culture to the action of disinfectants is clearly shown in the following tables:—

TABLE V.—*B. Typhosus* (*S.S.*), 48 *hours' Broth Culture at* 22° *C.*

Room Temperature 15°—18° C.

Sample	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Fluid W²	1 : 90	×	.	.	.	.	.	72 hours	37·5° C.
Carbolic Acid	1 : 120	×	.	.	.	.	.	,,	,,

Carbolic Acid Co-efficient = 0·75.

TABLE VA.—*B. Typhosus* (*S.S.*), 24 *hours' Broth Culture at* 37° *C.*

Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Fluid W²	1 : 90	×	×	×	.	.	.	72 hours	37·5° C.
Carbolic Acid	1 : 110	×	.	.	.	.	.	,,	,,
,, ,,	1 : 133	×	×	×	×	×	×	,,	,,

Carbolic Acid Co-efficient = 0·75 (average of 0·82 and 0·67).

It is interesting to note that in spite of this difference in resistance the carbolic acid co-efficients found for the disinfectant tested are practically identical. The culture grown at 22° C. was allowed twice the incubation period of that grown at blood heat, and should therefore, but for the influence of temperature, have shown the greater power of resistance.

5th. *Temperature of medication.*—No scheme can be considered satisfactory which does not take into account the temperature during medication. Slight variations in temperature of one or two degrees do not seriously affect the

results obtained by our method, but if the standardizing of disinfectants is to become a question of international interest —and we trust it may—then a standard temperature will require to be established. In our own practice we have adopted 15° C. to 18° C. as the range of temperature most easy of attainment throughout the year. The influence of this factor is felt in two different directions: In the first place emulsions prepared from certain disinfectants at 5° C. will be found to yield a very much lower co-efficient than those made from the same disinfectant at 15° C., the explanation in this case being that the ultimate globules of the disinfectant at the higher temperature are in a much finer condition and more evenly distributed. Further it will be seen from tables VI. and VIA. that the bactericidal action of carbolic acid is *at least* 50 per cent. greater at 37° C. than at 16° C. The influence of temperature may be less marked in the case of other disinfectants, but we think that the example given will serve to prove that this is a factor of the first importance.

TABLE VI.—*B. Coli (Escherich)*, 24 *hours' Broth Culture at* 37° *C.*

Room Temperature 16° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Carbolic Acid.....	1 : 70	.	.	.	.	.	.	48 hours	37° C.
,, ,, ...	1 : 80	×	.	.	.	.	.	,,	,,
,, ,, ...	1 : 90	×	×	×	.	.	.	,,	,,
,, ,, ...	1 : 100	×	×	×	×	×	×	,,	,,
,, ,, ...	1 : 110	×	×	×	×	×	×	,,	,,

TABLE VIA.—*B. Coli (Escherich)*, 24 *hours' Broth Culture at* 37° *C.*

Room Temperature 37° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Carbolic Acid.....	1 : 70	.	.	.	.	.	.	48 hours	37 C°.
,, ,, ...	1 : 80	.	.	.	.	.	.	,,	,,
,, ,, ...	1 : 90	.	.	.	.	.	.	,,	,,
,, ,, ...	1 : 100	.	.	.	.	.	.	,,	,,
,, ,, ...	1 : 110	.	.	.	.	.	.	,,	,,

6th. *Variations in vital resistance of the same species.*—That cultures of the same organism, obtained from different sources, show marked variations in resistancy is a fact too patent to all investigators to require further corroboration. We content ourselves, therefore, by calling attention to tables VII. and VIIa.

TABLE VII.—*Staph. p. aureus, 24 hours' Broth Culture at 37° C.*

Room Temperature 15°—18° C.

Sample[1]	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Carbolic Acid[1] ...	1 : 70	×	×	.	.	.	.	96 hours	37° C.
Carbolic Acid[2] ...	1 : 90	×	×	.	.	.	.	,,	,,

[1] Culture obtained from Major Firth.
[2] ,, ,, Dr. Klein.

TABLE VIIa.—*B. Typhosus, 24 hours' Broth Culture at 37° C.*

Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Carbolic Acid[1] ...	1 : 70	×	×	.	.		.	48 hours	37° C.
Carbolic Acid[2] ...	1 : 100	×	×	.	.	.	.	,,	,,

[1] Culture obtained from Major Firth.
[2] ,, ,, in Author's laboratory.

It will be noted that this is a factor which ceases to be of interest in the presence of a standard control.

7th. *Variations in vital resistance of different species.*—Here again we have a fact which must be well known to all

investigators. It may not be so generally known, however, to what extent these variations may work out in practice.

In tables VIII and VIIIa. will be found the carbolic acid co-efficients of an ordinary coal-tar disinfectant for *Staph. p. aureus* and *B. typhosus*.

TABLE VIII.—*Staph. p. aureus, 24 hours' Broth Culture at 37° C.*

Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Disinfectant W³...	1 : 80	×	×	×	.	.	.	48 hours	37° C.
Carbolic Acid.....	1 : 80	×	×	×	.	.	.	,,	,,

Carbolic Acid Co-efficient = 1·0.

TABLE VIIIa.—*B. Typhosus (Kral), 24 hours' Broth Culture at 37° C.*

Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Disinfectant W³...	1 : 250	×	×	.	.	.	.	48 hours	37° C.
Carbolic Acid.....	1 : 80	×	×	.	.	.	.	,,	,,

Carbolic Acid Co-efficient = 3·1.

8th. *Proportion of culture to disinfectant.*—This is perhaps the most important factor of all, and yet it is the one which is most frequently ignored. When the casual reader learns that a certain disinfectant is capable of destroying certain organisms within a specified period of time he accepts the statement as a valuable contribution to our knowledge of the article in question. Yet the absence of this factor entirely robs the statement of any value it might otherwise have. It is in cases such as the following that we find the strongest argument in favour of a standard control.

TABLE IX.—*B. Typhosus (Kral), 24 hours' Broth Culture at 37° C.*

(Taking 5 c.c. diluted Disinfectant + 5 c.c. Broth Culture).
Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Disinfectant A²/03	1 : 450*	×	×	.	.	.	.	48 hours	37° C.
,, ,,	1 : 485	×	×	×	.	.	.	,,	,,
,, ,,	1 : 525	×	×	×	×	×	.	,,	,,
Carbolic Acid.....	1 : 75	×	×	×	.	.	.	,,	,,

Co-efficient $\frac{4.8.5}{7.5} = 6.5$.

*Allowing for extra diluent introduced with Culture.

TABLE IXA.—*B. Typhosus (Kral), 24 hours' Broth Culture at 37° C.*

(Taking 5 c.c. diluted Disinfectant + 5 drops Broth Culture).
Room Temperature 15°—18° C.

Sample.	Dilution.	Time culture exposed to action of disinfectant—minutes.						Sub-Cultures.	
		2½	5	7½	10	12½	15	Period of Incubation.	Temperature.
Disinfectant A²/03	1 : 700	.	.	.	.	.	.	48 hours	37° C.
,, ,,	1 : 800	×	.	.	.	.	.	,,	,,
,, ,,	1 : 900	×	×	×	.	.	.	,,	,,
Carbolic Acid.....	1 : 80	×	×	×	.	.	.	,,	,,

Co-efficient $\frac{11.0.0}{8.0.0} = 11.2$.

The Council of the Sanitary Institute has recently been asked to appoint a Committee to inquire into the desirability of establishing a standard bacteriological method for determining the efficiency of disinfectants, and to take such steps as may be necessary for ensuring the legal control of disinfectants.

(B.) CHEMICAL METHODS.

As already pointed out, a full chemical analysis of a given disinfectant is desirable, owing to the influence of foreign substances upon its germicidal value. Especially when the active ingredient is volatile, it is necessary to test

from time to time the chemical strength of the material, as there have been several instances in which neglect of this precaution has allowed the use of an article which has been found to be of no value in preventing the spread of the infection. The methods of analysis obviously depend on the kind of substance to be employed, and may frequently involve much labour and skill. It is extremely important, however, that all disinfectants should be purchased with an analysis, and that samples should be taken from bulk after the order has been executed, in order that the medical officer may be assured that the material is equal in strength to that which has been prescribed. It would exceed the scope of this chapter if all the methods which might be of service were described at length. A selection has therefore been made of some of the quantitative tests which may be of use in identifying an unknown disinfectant.

For any exact analysis, a laboratory, and such special skill, knowledge, and training as no engineer or medical man can possess, is indispensable; hence such questions should be referred to a competent chemist. But there is always an advantage in being able to quickly and roughly determine factors, like the strength of chloride of lime, etc., It has already been pointed out that disinfection in ignorance is almost worse than no disinfection at all. In the following sketch a knowledge of elementary quantitative analysis is assumed; further details will be found in the various manuals.

Chloride of Lime.—As already explained (p. 84), the available chlorine is that existing as hypochlorite, $Ca(ClO)_2$; this easily breaks up into chloride, $CaCl_2$, and free oxygen, O_2. The usual way of estimating it is by standard solutions of iodine and arsenious acid, using starch as an indicator. The latter is not permanently blued until all the arsenious acid has been oxidized to arsenic acid.

All volumetric solutions are usually made decinormal—*i.e.*, one-tenth equivalent in grammes of the active agent in one litre; then 1 c.c. of one solution is equivalent to 1 c.c. of another.

Iodine Solution.—Dissolve 12·65 grammes of iodine with about 20 grammes of potassium iodide in a litre of water.

Arsenious Solution.—4·942 grammes of pure arsenious oxide and 20 grammes of sodium bicarbonate are dissolved in a litre of water.

Take 10 grammes of chloride of lime, triturate it in a mortar with successive small quantities of water, and transfer the whole gradually through a funnel into a stoppered litre flask. For each determination take out 10 c.c. of the well-shaken turbid fluid (to decant the clear solution gives a lower result—*Fresenius*), equal to a decigramme of the powder. Add from a burette the arsenious solution in slight excess—*i.e.*, until a drop ceases to produce a blue spot on ozone paper (KI and starch). Then add fresh starch paste, and run in iodine solution from another burette until there is a slight permanent blue colour. The number of cubic centimetres of iodine solution required gives the number of c.c. of arsenious solution that have been added in excess; subtract this from the total added, and the number of c.c. of the standard arsenious solution which are equivalent to a decigramme of the chloride of lime is obtained. Each c.c. of the decinormal arsenious acid is equal to $\frac{1}{10000}$ of an equivalent of available chlorine, or ·00354 gramme. The iodine solution should have its strength determined by the arsenious acid before each series of experiments. It keeps fairly well in the dark.

The same method can be used for the examination of chlorinated soda and potash, Hermite liquid (p. 89), bromine and iodine water, tincture of iodine, chlorine water, and indeed most oxidants.

Sulphites and Sulphurous Acid.—The solution must be very dilute, containing not more than 0·05 per cent. of SO_2 (*Bunsen*), then iodine converts sulphurous acid into sulphuric. If sulphite powders are examined, the method is exactly as with chloride of lime, omitting the arsenious solution, but adding starch paste and running in standard iodine until the permanent blue tint is obtained. One c.c. of iodine = ·0032 gramme of SO_2.

The same process answers for most reducing agents, such as sulphuretted hydrogen, etc., but not for ferrous sulphate, which is determined by adding sulphuric acid and running in standard permanganate till the pink colour persists.

To test for the presence of sulphites in food, two portions should be strongly acidified by dilute pure sulphuric acid, and over each a piece of paper moistened with lead acetate should be suspended. To one should be added some pure granulated zinc, so as to obtain a slow evolution of hydrogen.

If much frothing occurs, water must be added. The two are left for half an hour in a warm place. If the lead paper be blackened only over the one containing the zinc, the presence of sulphite is almost certain.

Peroxide of Hydrogen is marked in commerce "10 or 20 volumes," meaning the number of times its volume of oxygen that is given off when it is treated with peroxide of manganese. An easy way of ascertaining this is as follows:

A flask with cork and delivery tube is arranged to deliver the gas into a graduated measuring tube holding 200 c.c. filled with water and inverted in a basin or pneumatic trough. 10 c.c. of the hydrogen peroxide solution are measured into the flask. About a gramme of finely-powdered manganese dioxide is wrapped in a piece of paper, slipped into the flask, and the cork at once replaced. On shaking, the available oxygen is evolved. By warming the flask the last of the oxygen is removed, and is then measured. It can, of course, be calculated into weight. A rough idea of the quantity may also be obtained by adding to the diluted solution in a test-tube a few drops of potassium dichromate, then dilute sulphuric acid and ether. The intensity of the purple colouration of the ether layer is compared with that produced by a sample of known strength. This cannot be recommended except as a qualitative test.

Boric Acid.—A quantitative determination is tedious, but its presence in milk, etc., may be ascertained as follows: Render the sample alkaline with carbonate of soda, and burn to ash. Warm the ash for a short time with a very slight excess of dilute HCl, and filter. Dip into the filtrate, half-way, a strip of turmeric paper, made from the fresh tincture and dry in a water bath; if boric acid be present there will be a rose-red colouration, turned dark dull blue by weak soda solution. Cassal and Gerrans apply this reaction to the quantitative estimation.[1]

A few metals can be determined by volumetric processes, but as a rule, methods of precipitation and weighing are adopted. Mercury, when present as chloride or iodide, can be extracted by shaking with ether. In commercial preparations of the cyanide Meillère found 77 to 81 per cent. Hg instead of the theoretical 85.[2]

Permanganate (Condy's Fluid).—A known volume of a decinormal solution of oxalic acid is placed in a beaker or

[1] *Analyst*, 1903, p. 36. [2] *Journ. Pharm. Chem*, 1901, xiv., 356.

porcelain dish, rendered strongly acid with dilute sulphuric acid, and the permanganate solution, properly diluted, run in from a burette until a permanent pink tinge is produced. The reaction is—

$$5H_2C_2O_4 + K_2Mn_2O_8 + H_2SO_4 = K_2SO_4 + 2MnSO_4 + 10CO_2 + 8H_2O.$$

Therefore 5 equivalents of oxalic acid require for oxidation 1 equivalent of permanganate, equal to 5 atoms of available oxygen.

Phenol.—Water is estimated by shaking the sample in a graduated tube with half its volume of a saturated solution of common salt. The diminution of volume of the phenol indicates the amount of water present. "Calvert's No. 1" contains none, crude acids often contain 10 to 17 per cent. Anhydrous cresol shaken up with three volumes of brine increases in volume by about 5 per cent. If the cresol contains water, its volume either does not alter, or decreases slightly.

Koppeschaar's method of determining the actual amount of phenol is as follows:—Shake up bromine with water at 20° C.[1] To determine the phenol-equivalent of the bromine water, a sample of Calvert's No. 1 acid (crystals) is boiled for a short time to remove traces of moisture, 0·25 gramme weighed into a well-stoppered flask and dissolved in 100 c.c. of water, the bromine water run in from a stoppered burette, with constant shaking, until there is a good excess, as shown by the colour. After half-an-hour's standing, if the excess has disappeared, more bromine must be added, and the mixture again shaken and allowed to stand; the total amount added must be carefully noted, excess of potassium iodide is added, and the amount of liberated iodine ascertained by standard thiosulphate and starch in the well-known manner. This free iodine corresponds to the bromine in excess; deduct this from the total bromine added, and the amount of bromine water necessary to precipitate 0·25 gramme of pure phenol is obtained, and from this is calculated the phenol-equivalent of each cubic centimetre of the bromine solution. The final result is tribromophenol.

$$C_6H_5.OH + 3Br_2 = C_6H_2Br_3.OH + 3HBr.$$

The operation repeated with the sample under examination

[1] Such a solution keeps better than water saturated with bromine in the cold and may be preserved in well-stoppered bottles in the dark

gives the phenol strength. For soaps and powders Fresenius and Makin[1] treat a known weight with dilute sulphuric acid in slight excess and distil rapidly in a current of steam. The distillate is titrated as above, except that these authors prefer to use a standard solution of sodium bromide and bromate (p. 99) instead of bromine water.

The author has found that the loss of bromine by volatilization during the process is trifling if the operation is properly performed and the solution be sufficiently dilute. To avoid this possible error, however, Hymans mixes the sample with about 10 c.c. of 30 per cent. hydrobromic acid and runs in semi-normal permanganate to liberate the bromine so that it immediately combines with the phenol. Towards the end a few drops of chloroform are added to cause agglomeration of the precipitate (not excess, or it will dissolve the bromine and give too high results), and the final point is ascertained by taking out drops of the liquid and adding them to spots of carmine solution on a white tile: when the pink colour is just bleached, there is excess of bromine.

Samples containing cresol and higher phenols require proportionately less bromine, so the result is lower than the truth, if the bromine equivalent is calculated to phenol. A process for anhydrous mixtures of phenoloids consists in determining the solidifying point by cooling in a narrow tube and adding a minute crystal of pure phenol to aid the solidification. The melting point is then compared with ready-made mixtures of known composition (or with a table).

If the tribromo-precipitate be collected on a filter paper and dried over sulphuric acid, tribromophenol being crystalline, and tribromocresol and the others liquid, the latter soak into the paper, and the two fractions can be separately weighed. The liquid portion should be calculated as cresol and higher homologues.

Fractional distillation of the phenoloids gives doubtful results, as the boiling point ascends gradually.

Tar Preparations.—The ingredients of these may be divided into four groups:—

1. *Neutral* bodies not combining with acids or alkalies, divided into—

(*a*) *Light oils*, containing benzene and the homologues.

(*b*) *Heavy oils*, containing naphthalene, anthracene, etc.

[1] *Zeits. Anal. Chem.*, 1896, xxxv., 325.

The antiseptic value of these is slight. They are classed as neutral tar oils.

2. *Basic* bodies, combining with acids—*e.g.*, aniline, pyridine, etc. As their antiseptic value is high they may with advantage be present in disinfectant fluids. The commercial importance of aniline has led to this group being extracted in making phenol and cresol preparations. Hence there has been a reaction in favour of crude coal-tar preparations, instead of the purely phenol compounds that were formerly almost exclusively in vogue, although the neutral bodies in the former are undoubtedly of little value.

3. *Phenols,* soluble in alkalies, but not really acid bodies. The valuation of these preparations is based on the proportions of these constituents.

A. 10 c.c. of the oil are taken in a graduated tube, 20 c.c. of 10 per cent. caustic soda added, and the whole well shaken, and allowed to stand. The phenoloids dissolve, while the neutral (and basic) substances collect as an oily layer; below, if they are heavy oils; at the top, if they are light oils. If they will not separate distinctly, which often happens, add 10 c.c. of petroleum ether and shake, measure the amount of the mixture and subtract the ether. The result is only approximate, but for ordinary purposes this method is considered sufficient, the volume obtained being returned as the neutral (and basic) tar oils present.

B. For a more exact examination a larger quantity must be taken, 50 or 100 grammes of the original liquid, treated with soda as above, and the two liquids separately examined, after measuring their quantity.

(*a*) The portion insoluble in soda is evaporated below 100° C. to remove the ether; naphthalene and anthracene may crystallize out on standing, and may be identified by their melting and boiling points. The liquid which will not crystallize is washed in a graduated tube with 20 per cent. sulphuric acid to remove the bases as sulphates. Notice again the diminution of volume (result only approximate). The acid solution is distilled with aqueous potash; the bases (aniline, pyridine, etc.) come over and can be tested. If the quantity allows, dry them by fused calcium chloride, determine their boiling and melting points, their chemical reactions, and the nature of their platinum double salts. The portion insoluble in all reagents can be tested by its physical properties.

(*b*) The fraction soluble in soda, containing the phenoloids, is fractionally precipitated by successive small quantities of dilute sulphuric acid, whereby the carbolic acid is concentrated in the first fraction; then the melting points of the several fractions are taken, as above described.

In some cases where the tar acids have been rendered soluble by the addition of a resin soap, the following method may be used:—Petroleum ether is added to a known weight of the disinfectant until the tar oils are dissolved and the resin soap has separated. After washing the resin soap with ether, it can be dissolved in water and decomposed by acid, and after precipitation with alcohol, weighed and its acidity determined. A direct titration of the original disinfectant gives the amount of alkali present, and the ash the total amount of mineral matter.

Carbolic Powders.—In the case of powders made with lime, or others in which the phenol exists in combination, neither direct distillation, not extraction with ether, give a correct result unless the powder is first acidified. Allen mixes 50 grammes in a large mortar with 5 c.c. of water, and drops in gradually with constant stirring, so as to keep down the heat, 50 per cent. sulphuric acid. The addition, which takes some hours, is continued till a fragment of the powder shows an acid reaction when moistened with water. If the mixture be pasty, it must be triturated with sand to make a granular powder. After standing covered for two hours, it is transferred to a large Soxhlet tube and extracted with ether or benzene. On distilling off the solvent below 110° C., the crude tar products are left, and can be further tested.

To distinguish between preparations made from wood-tar and from coal-tar is comparatively easy; in mixtures the identification of the source (shale oil, blast furnace oil, etc.) becomes more difficult.

1. Coal-tar acids coagulate collodion, B.P., wood creosote does not.

2. A neutral aqueous solution of ferric chloride gives with phenol a deep violet colour, with wood-creosote a yellowish or greenish-brown tint.

3. *Hager's Test.*—Thirteen volumes glycerine are diluted with 1 volume water. One volume of the sample to be tested is well shaken in a stoppered burette with 3 of the diluted glycerine, and allowed to stand. If the creosote be pure, the volume will remain unchanged. If reduced, the glycerine layer is drawn off and the remaining creosote again shaken with 3 volumes of the dilute glycerine, and the volume again observed. The undissolved portion includes the wood-creosote, but may also contain products from shale or blast-furnace oil; the chief distinction lies in the odour. The soluble portion may be diluted with water, the coal-tar acids extracted with chloroform, and the latter separated and distilled off. So separated, the phenoloids from blast-furnace and shale oils give with ferric chloride a violet-blue colour changing to brown, instead of a permanent deep violet, as with ordinary phenol.

Sulphuretted hydrogen should be tested for with dilute sulphuric acid and lead paper. Powders containing it emit an offensive odour, and are usually excluded by the terms of the contract. Sulphites and hypochlorites can be determined as at pp. 472, 473. As sulphurous acid powders oxidize on keeping, it is important to ascertain not only the "available" sulphurous acid, but also the quantity oxidized to sulphuric acid.

It is impossible to give a general process for the detection or estimation of the multitude of organic bodies that have been introduced for sanitary purposes. It may be mentioned that in the above division of the tar preparations into acid, basic, and neutral bodies, the following substances will appear in the places indicated:—

(*a*) *With the neutral oils:* Benzene, naphthalene, anthracene, vaseline, paraffins, pyrrol, essential oils, thymol, camphors, alcohol, ether, and neutral bodies generally.

(*b*) *With the bases:* Aniline, pyridine, quinoline, ammonia, compound ammonias, and volatile alkaloids such as trimethylamine, nicotine, etc.

(*c*) *With the acids:* Phenol, cresol, etc., resorcin, benzoic, and other aromatic acids, fatty and resin acids (distinguished by non-volatility and other physical characters; resin soap gives a brown colour and is not coagulated by strong soda solution, thus differing from a fatty soap).

The specific gravity of crude carbolic acid should be between 1·05 and 1·065; if it is less it is most likely adulterated with light tar-oil, in which case the specific gravity is often between 1·04 and 1·045.

Carbolic Acid in Soaps.—Five grammes of the soap are dissolved in warm water, and 20 or 30 c.c. of 10 per cent. caustic soda added. After cooling, the solution is shaken with ether to remove any hydrocarbons (terebene, camphor, etc.). The alkaline liquid is next mixed with saturated brine, which precipitates the soap and leaves the phenols in solution. It is then filtered, the soap again shaken up with brine and the washings added to the filtrate, and the liquid made up to 1 litre. 100 c.c. of the solution (= 0·5 gramme of the soap) are placed in a separator, acidulated with dilute sulphuric acid, and titrated with bromine water as at p. 475.

For cresol soaps Schmatolla[1] decomposes with dilute sulphuric acid in the presence of petroleum spirit, separates and evaporates off the solvent, and weighs the residue of fatty acids, cresols and hydrocarbons. This is then dissolved in alcohol and titrated with potash and phenolphthalein, which gives the fatty acids alone, and by difference the cresols and hydrocarbons. To estimate the latter, they are extracted from an aqueous solution of the original soap by shaking with petroleum ether: this is then separated and washed with 3 per cent. potash, evaporated and weighed.

Salicylic Acid and other Preservatives in Foods.—The articles are cut up if necessary, and extracted, first with

[1] *Chem. Zeit.*, 1903, xxvii., 634.

two portions of cold, then with about three of boiling water, separating any fat by passing through a wet filter, or in some cases by allowing the whole to cool and removing the layer of fat. The volume of the aqueous liquid should not be unduly large. Milk must be coagulated by a little acetic acid and gentle warming, then filtered and the whey examined. Solutions containing gummy or viscous matters, or colouring matters soluble in ether, can be precipitated by neutral acetate of lead, filtered, the filtrate freed from lead by sulphuretted hydrogen, and the latter expelled by warming. The prepared filtrates should then be neutralized by soda, evaporated to a convenient bulk, acidified with dilute sulphuric acid, and extracted with ether in a separator. The ethereal solution, besides salicylic acid, will contain any phenol, cresol, benzoic and other aromatic acids, thymol, essential oils, ethers, perhaps glycerine, bitter principles, resins, glucosides, alkaloids, and sugars in traces, lactic and vegetable acids. If acetate of lead has been used, the resins and bitters will have been removed. Distil off the ether, make up to a measured volume with water, and divide into several portions. Notice the odour, taste, and appearance, and apply special tests. If glycerine be sought for, neutralize with soda, extract with alcohol and ether, distil off the solvent and evaporate at a gentle heat; the nearly pure glycerine can be weighed and afterwards tested.

In an aliquot part the salicylic acid can be determined by adding neutral ferric chloride cautiously (iron alum is better), and imitating the colour in another tube by a standard solution of salicylic acid. As some other substances are extracted which simulate salicylic acid, it has been recommended that petroleum ether, or a mixture of that solvent with ordinary ether, should be used for extraction, and the German government prescribe that in testing wines, not more than 50 c.c. of the sample should be used.[1]

If phenol or resorcin be present, the comparison must be effected in alcoholic solution (absolute), with alcoholic ferric

[1] *Analyst*, 1903, p. 4.

chloride. Thus even 1 part of salicylic acid with 800 of phenol may be estimated.[1] In testing for resorcin H. Bodde[2] adds a few drops of sodium hypochlorite to a watery or alcoholic solution of resorcin; a violet colour, rapidly changing to yellow, is produced. On warming or adding excess, the liquid becomes dark brown. One part of resorcin in 10,000 of water will still show this reaction. Carbolic, salicylic, benzoic, and other allied acids do not give it, but may turn the liquid slightly yellow on warming. Pyrotatechol turns green, hydroquinone yellow and red. Another test is to first add liquor ammoniæ and then a few drops of hypochlorite, when the liquid will give a reddish-violet colour, turning green on boiling. The colour is not taken up by benzene. The reaction is not shared by salicylic nor benzoic acid, nor by antifebrin, but phenol gives a greenish-blue, partly soluble in benzene. The colours are changed to red by dilute sulphuric acid.

Phenol, thymol, β-naphthol, and salicylic acid can be estimated by iodine and thiosulphate as follows:—2 grammes are dissolved in water with about 3 grammes of caustic soda, and the solution diluted to 250 or 500 c.c. 5 or 10 are measured into a flask, warmed to 60° C., and standard iodine added till the liquid is strongly yellow. On agitation a bright red precipitate will fall. After cooling, the liquid is titrated with standard thiosulphate to ascertain the excess of iodine. Each molecule of phenol (94) consumes 6 atoms iodine. *β-naphthol* gives a dirty green precipitate; the factor is 0·3784. With *salicylic acid* at 60° C. the bright red precipitate should not be formed until the iodine is in excess, and should be increased by acidulation. If too little alkali be present, a yellowish-white precipitate is formed; in this case more soda must be added. The multiplier is 0·1813. *Thymol* gives a brownish-red precipitate, and requires no heat. It takes up 4 atoms of iodine.[3]

[1] A. Fajans, *Chem. Zeitung*, 1893, vol. v., p. 69.

[2] *Nederl. Tydschr. v. Pharm.*, May, 1889.

[3] *Berichte*, 1890, p. 2753.

In a mixture of two of these bodies, if the sum of their weights is known, as well as the iodine equivalent of the mixture, the amounts of the two constituents can be calculated.

Formalin can be recognized in foods by distilling and proving the presence of a volatile aldehyde in the distillate by means of a magenta solution bleached by sulphurous acid. In milks, the presence of formalin is indicated by a rose-violet colouration when strong sulphuric acid is added, at the point of junction of the two liquids (Hehner). This test can be applied to other solutions, by adding one drop of milk before the addition of the acid.

Medicated Wools.—Hoseason[1] drew attention to the immense variation in the strength of these preparations as found in commerce. His method of analysis consists in shaking weighed quantities (10 grammes) of the wools with water (1 litre), and determining the amount of the effective constituent in the following way:—

1. *Phenol,* by the volumetric bromine process (p. 475).

2. *Boric Acid,* by evaporating one-fortieth (25 c.c.) of the solution to dryness with 5 c.c. of a strong solution of sodium carbonate, the latter being previously standardized. The loss of carbonic acid was estimated by weight in a modification of the usual CO_2 apparatus. The boric acid was thus determined by difference.

3. *Mercuric Chloride.*—Scherer's method with hydrochloric acid and decinormal thiosulphate is inapplicable if the quantity of mercury is small. A colorimetric method based on the depth of the brown colour with sulphuretted hydrogen may be used. Some results obtained with commercial antiseptic wool dressings are as follow:—

Carbolic, in five samples: 1·06, 1·07, 0·69, 0·25, 5·08 per cent.

Boric, in five specimens: 36, 21·6, 27·1, 15·8, 14·4 per cent.

[1] *Chem. and Drug.*, Feb. 18, 1893. The same Journal, 1898, p. 235, gives a volumetric process for the assay of boric acid in lint.

Corrosive Sublimate, in two: none, and 1 in 8,000 to 9,000.

Dr. Thresh distils carbolized gauze with a little zinc and hydrochloric acid to cause steady boiling.[1]

Tests of Penetration in Gaseous Disinfection.—M. Calmette[2] measures the penetration of SO_2 by placing in the room at various levels graduated glass tubes filled with dry sand coloured with blue litmus. The tubes are 5 to 10 mm. in diameter and 1 metre long, are closed at one end and plugged at the other with cotton wool. The sand will be reddened as far as the SO_2 has reached. It is stated that a penetration of 25 centimetres corresponds with the destruction of B. typhosus and 40 with that of B. diphtheriæ. For formaldehyde he colours horse-serum with fuchsine and dries at 40° C. A few scales of this preparation are introduced at intervals along a tube filled with dry sand or cotton wool: where the formaldehyde has penetrated the serum will be rendered insoluble, and the point can be ascertained by afterwards passing in water.

[1] *Chem. and Drug.*, Aug. 3rd, 1901.

[2] *Acad. de Méd.*, May 5th, 1903; *Brit. Med. Journ.*, May 23rd, 1903.

INDEX.

A

Absynthol, 287
Acarus, 228
Acetamide, 247
Acetanilide, 250
Acetic acid, 213, 324, 415
,, ether, 324
Acetone, 197, 234, 328, 384
Acetous fermentation, 140, 325
Acetozone, 326
Acetyl-hydrogen peroxide, 120
,, peroxide, 325
Acetylene, 329
Acids, general antibacterial action of, 96, 122, 128, 136, 325, 329, 374-381, 397, 406, 419
Acridine, 253
Actol, 193
Aerated waters, 145
Aeration, purification by, 111
Aerobic bacteria, 144, 233
Air, disinfection of, 356
,, in steam, apparatus for securing absence of, 56
,, ,, disadvantages of, 55
Airol, 192
Albuminate of mercury, 187
Alcohol, 197, 321, 384, 411, 422
,, methylic, 234
Aldehyde, ethyl, or acetic, 299
,, formic, 294
Alexines, 408
Alformant lamp, 308, 313, 319
Algæ, 19
Alkalies and alkaline earths, salts of, 147, 421
Alkalies, caustic, 147
Alkaloids, 247
Allen's hygiene disinfecting fluid, 227
Allyl isothiocyanate, 328
Alum, 409, 420 (*also see* Aluminium salts)
Aluminium and its salts, 173-175, 212, 291, 391, 409, 419, 435
,, for water purification, 161, 364
Alumnol, 242, 388
American disinfection practice, 76, 87, 92, 307, 338
Amidobenzene (*see* Aniline)
Amido-compounds, 246-251
Amines, 247
,, process, 247
Aminol, 248
Ammonia and ammonium salts, 151, 246, 425
Amylamine, 248
Amyloform, 320
Anaerobic bacteria, 144
Analysis, methods of, Chap. XVI., 451
Andeer's lotion, 233
Anderson's process, 161
,, solution, 87
Andreoli's ozonizer, 116
Aniline, 249, 336
,, dyes, 250
Animals, infected, 202, 353, 354
Anisic acid, 276
Annidaline, 282
Anthracene, 199, 253
Anthrax, 13, 31, 33, 38, 52, 58, 91, 94, 98, 100, 145, 152, 154, 158, 179, 180, 184, 192, 196, 197, 202, 208, 213, 220, 222, 225, 229, 248, 260, 270, 287, 297, 309, 312, 314, 316, 322, 323, 355, 368, 397
Antibacterikon, 118
Antifebrin, 250
Antimony, 413
Antinonnin, 245
Antipyrin, 252
Antisepsin, 250
,, Radlauer's, 143, 155
"Antiseptic," definition of, 2, 111, 159
Antiseptin, 185
Antiseptol, 263
Antitoxines, 8, 408
Anusol, 233
Apyonin, 251
Argentamine, 193
Argonine, 193
Aristol, 105, 282
Army Medical Service Regulations, 446
Aromatic compounds, 198 *et seq.*, 278, 410
Aromatic substances, 3, 264, 325
,, vinegar, 325
Arsenic and its compounds, 176, 355, 399
Asaprol, 242
Asepsin, 250
Aseptine, 139
Aseptol, 212
Ashes and cinders, 18
Ashpits, 333
Aspergillus, 145, 148, 181, 383
Asphalt (*see* Streets, 350)
Auramines, 251
Australian salt, 143
Autoclave, Trillat's, 301
Available chlorine, 84

B

Bacillus anthracis (*see* Anthrax)
,, enteritidis sporogenes, 351
,, subtilis, typhosus, tuberculosis (*see under specific names*)
Bacon, 416
Bacteria, effects of gases on, 144
,, modes of combating, 6
,, products of, 144, 161
Bacteriological tests, 451
Bacteriology, 4-9
Bacterium termo, 144
Bakehouses, 353
Balsams of Peru and Tolu, 264, 276
Barium peroxide, 120
Barmenite, 143
Beer, preservation of, 107, 134, 145
Benzanilide, 267
Benzene, 199, 234, 253
Benzenesulphonic acid, 212
Benzoboric acid, 142, 266
Benzoic acid and benzoates, 264-268, 407, 410, 420, 421
,, aldehyde, 266
,, gauze, 391
Benzoin, tincture of, 277
Benzonaphthol, 268
Benzosol and Benzoparacresol, 267, 407
Berlinite, 143
Betanaphthol, 240, 388, 399, 481, 482
Betol, 242, 270, 388
Beverages, preservation of, 121, 134, 145, 146, 272, 273
Bicarbonate of soda, 147, 150
Bichromate of potash, 175
Bilge water, disinfection of, 152, 181
Bilharzia, 251
Biltong, 408
Bischoff's spongy iron process, 161
Bismuth salts, 192, 210, 233, 241
Bisulphate of soda, 377-381
Bisulphide of carbon, 138
Bisulphites, 131, 134, 419
Bitter herbs, 410
Bitumens, 16
Blast furnace creosote, 215
Bleaching powder, 86
Blocks, disinfecting, 199, 284
Blood, difficulty of sterilizing, 353
Books, disinfection of, 51, 61, 314, 345
Borax, 141
Boric acid and borates, 139, 146, 286, 324, 330, 389, 395, 398, 409, 416, 419, 420, 421, 424, 474, 482
Borneol, 287
Boroglyceride, 142, 328
Bottled liquids, preservation of, 107, 121, 134, 145, 146, 272, 273, 419
Botuline, 415
Bradford's disinfector, 35
Branalcane, 328
Bread and Bread-making, 250, 273, 353, 435
Brewing, 106, 117, 150, 192, 272, 283, 419, 436
Brine, action of, 97, 148, 417
Brockman's salt, 143
Bromide of ethyl, 105
Bromine, bromides, and bromates, 98, 207, 373, 390, 398
Bromoform, 103
Bromonaphthalene nightlights, 99
Brussels Hygiene Congress, 423, 430, 433
Budenberg's steam disinfector, 71, 428
Bunter's Nervine, 283
Burial, 3, 149
Burnett's disinfecting fluid, 153
Burns and scalds, 388
Butter, preservation of, 134, 143, 145, 250, 273, 274, 433
Butyric acid, 163, 213

C

Cabs, 354
Cadaverine, 137
Calcium bisulphite, 135
Calomel, 407
Calvert's carbolic powder, 206
Camphene, 287
Camphine, 280
Camphoid, 287
Camphors, 278, 280, 284, 402
,, artificial, 280
Camphortar, 284
Camphylene, 288
Candles, fumigating, 100, 101, 285
Canned foods, 412, 426
Caraway, oil of, 283
Carbazol, 212
Carbide of calcium, 126
Carbolates, 190, 200, 201
Carbolic acid, 200, 401, 447, 461 (*see also* Phenol)
,, paper, 417
,, powders, 205-207
Carbon, 14
,, dioxide (*see* Carbonic acid)
,, disulphide, 138, 418
,, monoxide, 417
Carbonates, 147, 148, 150
Carbonic acid, 145, 390, 425
Carbo-sapol, 402
Carferal, 161, 162
Carvacrol, 281
Carvene and Carvol, 283
Caryophyllin, 283
Catechol, 233
Catgut, 386
Cats, 354
Cattle markets, 353
Cattle plague, 202
Cavities of the body, disinfection of, 388
Cedrene, 279
Chamberland filter, 20, 363
Charcoal, 2, 14-16, 404, 405

Charqui, 408
Cheese, 434
Chinese preservative powder, 143
Chinoline (*see* Quinoline)
Chinosol, 258-262, 337, 338
Chloral, 299
Chloralum, 175
Chlorates, 95, 405
Chloride of ammonium, 390
,, lime, 84, 86, 333, 338, 347, 350, 371, 383, 444, 447, 450, 472,
Chlorides, 97
Chlorinated soda (*see* Hypochlorites)
Chlorine, methods of preparation, 77, 448
,, modes of action, 78, 196, 197, 343, 371, 390
,, peroxide, 96
,, water, strength of, 83, 371, 389
Chloroform, 102, 294
Chlorol, 186
Chlorophenols, 210
Chloros, 85
,, distributor, 344
Chlorozone and Chlorogene, 88
Cholera, 17, 27, 87, 91, 94, 101, 119, 121, 136, 137, 145, 149, 158, 159, 183, 185, 204, 211, 212, 216, 219, 222, 224, 228, 241, 255, 256, 261, 269, 270, 278, 284, 297, 300, 314, 324, 329, 339, 340, 355, 363, 364, 368, 372, 381, 406, 442
Chromates, 175-176, 197
Chromium and its compounds, 175
Chrysarobin, 389, 395
Chrysoidine, 340
Cider, preservation of (*see* Beverages)
Cinnamic acid and Cinnamein, 276, 388, 410
Cinnamon, oil of, 283
Cisterns, 346
Citric acid, 121, 329, 378
Clark's process, 21
Closets, earth and water, 347 (*also see* Excreta, and the various reagents)
Clothing, disinfection of, 315, 336, 345; (*also see* Chap. III.)
Cloves, oil of, 283, 403
Coal dust, 16
,, tar and its products, Chap. VIII., 198
,, tar soaps, 393, 404
Coke, 16
Cold, 23, 24, 424
Collargol, 193
Collodion, 246
Condensation in heat disinfectors, 37
Condiments, 409, 422
Condy's Fluids, 168, 172, 474
,, powder, 171
Conine, 254
Cooking, 426
Copper and its salts, 156, 195, 291, 338, 353, 382, 435, 450
Corpses, 318, 345, 445 (*also see* Injections, Embalming, Cremation and Burial)
Corrosive sublimate, 179
Cowsheds (*see* Stables)
Cream, preservation of, 143, 431
Cremation, 4, 75, 346, 446
Creocide, 224
Creolin Jeyes', 222, 223, 337, 450
,, Pearson's, 217, 224, 395
Creosol, 235, 238, 239
Creosotal, 236
Creosote, coal-tar, 215
,, oils, 214, 215, 382
,, wood, 216, 234, 235, 410
Cresegol, 211
Cresochin, 262
Cresol or Cresylic acid, 200, 212, 213, 215, 391, 395, 401, 442, 476
Cresyl salicylates, 270
Crurin, 192
Culture media, 147
Cultures, bacterial, 260
Cumenol, 214
Cupralum, 160, 175
Cupric acetate, 159
,, chloride and sulphate, 158
Cuprous chloride, 157, 374
Cuts, treatment of, 387, 388
Cyanide of mercury, 189
Cyanogen, 146
Cyllin, 223

D

Definition of terms, 1, 2
Defries' disinfector, 74
,, siphon air controller, 55-57
Dejecta, disinfection of, 164
Deodorants generally, 2
Dermatol, 192
Desiccation, 3, 23-26, 149, 415
Diamine, 247
Diaphtherin, 257, 391
Diatomites, 207
Digestion, effect on (*see* Preservatives, effect on health)
Diphtheria, 8, 27, 68, 91, 92, 101, 156, 185, 189, 204, 218, 224, 228, 232, 254, 261, 265, 270, 302, 309, 314, 328, 354
Disinfectants, definition of, 1, 2, 8, 111, 159
,, standardization of, 393, 457-471
Disinfecting powders, 18, 201, 205-207, 288, 332, 350, 478
Disinfection of air, 356
,, internal, 101, 211, 216, 232, 233, 240, 241, 269, 276, 285, 286, 319, 326, 388, 405
,, primitive methods, 3, 349
,, public, 330

Disinfectors—
Bradford's, 35
Defries', 74
Doty's, 73
Equifex, 62
Fournier's, 74
Fryer & Alliott's, 74
Geneste-Herscher, 62-65, 318
Goddard's, 44
Henneberg's, 72
McLautlin's, 73
Manlove Alliott's, 47-49
Mayer's, 72
Ransome's, 36
Reck, 66
Rohrbeck's, 72
Schimmel's, 69
Thresh, 57
Thursfield, 59, 316
Washington Lyon's, 44, 47
formaldehyde, 300, 301, 308, 313, 316, 317
hot air, 32, 49, 334, 345
Distilled waters, 279
Distributors, 343, 344, 350
Dithiosalicylate, sodium, 277
Doty's steam disinfector, 73
Drains, 331
Dressings, antiseptic, 390
Dry heat, 32, 49, 384
,, rot, 382
Drying (*see* Desiccation)
Durenol, 214
Dust, atmospheric, 358
Dustholes, 333
Dyes, disinfectant, 250, 251

E

Earth, action of, 3, 347, 348
,, closets, 347
Eau Désinfectante Larnaudes, 159
,, de Javel, 85
,, ,, Labarraque, 85
,, ,, Saint Luc, 154
Eggs, preservation of, 150, 412
Egols, 211
Eka-iodoform, 320
Electricity, agency of, 11, 13, 14, 414
Electrolytic chlorine, 89, 93
Electrozone, 92
Embalming, 3, 16
Enzymes, 204, 265, 271
Equifex milk sterilizer, 432
,, sprayer, 300, 343
,, stove, 62
Erysipelas, 208, 210, 228
Essences, 279
Essential oils, 117, 121, 142, 278, 283, 289, 390, 402
Essets Fluid, 223
Ethyl acetate, 324
,, bromide, 105
,, iodide, 104
Ethyl nitrite, 124
Ethylenediamine, 193
Eucalyptol, 285, 390, 392, 395, 399
Eucalypto-resorcin, 286
Euchlorine, 95
Eugenol, 283
Eugoform, 238
Eugol, 286
Europhen or Europhene, 105, 231
Excreta, disinfection of, 143, 164, 178, 209, 221, 226, 229, 244, 314, 336, 348, 443

F

Fæces, disinfection of, 149, 218, 337, 347
Fairs, 353
Fats, preserving, 266
,, relation to disinfectants, 395
,, selection of, for soaps and ointments, 393
Fatty acids, action on B. subtilis, 213
,, ,, disengagement by iron salts, 163
Fermentations, checking, 106, 135, 140, 150, 177, 192, 195, 204, 209, 215, 232, 237, 244, 258, 265, 271, 273, 278, 281, 282, 283, 297, 321, 325
Ferric acid, 166
Ferric sulphate and chloride, 165
Ferrochlor, 166
Ferro-manganese, 166
Ferrous sulphate, 162, 205, 331, 448
,, sulphide, 162, 163
Filtration, 18-21
Fire, disinfection by, 77
Fires in disinfectors, 35
,, ,, streets, 3
Fish, bacterial disease in, 249, 414, 416
Flies, danger from, 350
Floors, 183, 188, 334, 346, 393
Fluoborates, 106
Fluorine and Fluorides, 105, 398, 421, 436
Food, preservation, 2, Chap. XIV., 145, 273 (*see special headings of preservatives*)
Foot and mouth disease, 278
Forbes water sterilizer, 360
Formaldehyde compounds, 135, 248, 421
,, disinfection, 74, 348, 335, 337, 344, 345, 346, 389, 449, 450
,, effect on lower fungi, 384
,, generators, 300
Formalin, 294, 401, 429, 444, 482
Formates, 141
Formic acid, 213, 324
,, aldehyde (*see* Formaldehyde)
Formogène Richard, 307
Fournier's disinfector, 74
Fowler's solution, 176

Fowl houses, 353
Francis's steam disinfector, 73
Fruit, preservation of, 135, 146, 273, 323, 409, 414
Fryer & Alliott's disinfector, 74
Fumigation, illusory, 335
,, with chlorine, 84, 343,
,, ,, copper chloride vapour, 160
,, ,, eucalyptus, 286
,, ,, formaldehyde, 248, 300, 405
,, ,, hydrochloric acid, 96
,, ,, hydrocyanic acid, 146
,, ,, iodine, 100
,, ,, nitric acid, 122
,, ,, phenol, 342
,, ,, pyridine, 254
,, ,, sulphurous acid, 129, 132, 205, 304, 342, 346
Fungi, agents antagonistic to, 134, 138, 160, 165, 176, 181, 245, 250, 297
Furfurane, 252
Furniture and Woodwork, 335, 345, 393
Furs (*see* Skins)

G

Gallic and Gallotannic acids, 277
Gannal's solution, 176
Gargles, 389
Garlic, oil of, 283
Gases, influence of on bacteria, 144
,, injection of, 390
,, mechanical purification of, 14
,, preserving food by, 144, 417
,, produced by bacteria, 144
,, properties, 33, 35
Gauze, iodoform, 103
Gauzes, medicated, 185, 187, 189, 190, 208, 243, 266, 275, 281, 390, 391
Gelatine, coating with, 414
Geneste-Herscher disinfectors, 62, 318
,, ,, water sterilizer, 359
Gentian violet, 250
Geosote, 326
Geranium, oil of, 283
Germol, 224
Germ theory of disease, 1
Glacialine, 143
Glutol, 319
Glycerine, 142, 146, 326, 388, 391, 395, 420
Glycerinum saponatum, 328, 404
Glycoformal, 315
Goddard, Massey and Warner's disinfector, 44
Gold compounds, 194
Gonococci, 193, 194
Gonorrhœa (*see* Injections)
Goulard's extract, 178, 388
Goux-Thulasne disposal of excreta, 348
Grain, cleansing and protection of, 135, 435
Guaiacol, 235, 237, 392, 407
Guaiamar, 328
Gypsum, 18, 148

H

Hair, infected, 355
Halogen derivatives of phenols, 209
Halogens, Chap. IV., 370, 397
Haloid organic compounds, 102
Hams, curing of, 143, 148, 236, 250, 273, 326, 328, 416, 420
Hands, sterilising the, 101, 105, 182, 218, 249, 322, 385, 387, 402
Heat disinfection, 4, Chap. III.
,, preservation by, 426
Heliotropin, 287
Helmitol, 249
Henneberg's steam disinfector, 72
Hermite process, 89
Hermophenyl, 190
Herring brine, 247
Hexamethylenetetramine, 248, 299, 311, 320
Heydrich's salt, 143
Hides, preserving, 177, 207
History of disinfection, 3
Holzine, 308
Homologues of phenol, 201, 214
Hops, essence of, 283
Hospitals, 77, 346
Hot air disinfectors, 34, 49
Hot solutions, 345
Houses, disinfection of, 156, 334
Hydrargyrol, 190
Hydrazine, 247
Hydrocarbons, 199, 214, 278, 329
Hydrochloric acid, 96, 328, 419
Hydrocyanic acid, 146
Hydrofluoric acid, 105, 106
Hydrogen peroxide, 118, 293, 346, 368, 405, 418, 429, 474
Hydronaphthol, 242
Hydroquinone, 233
Hydroxybenzenes, 232
Hydroxylamine, 247
Hydroxynaphthoic acid, 243
Hypochlorites, 84, 335, 371, 390, 397, 404
Hypodermic injections, antiseptic, 392

I

Ialine, 224
Incinerator, Sergeant's, 75
India, plague disinfection in, 346
Indole, 256
Influenza, 285
Infusorial earth, 18, 207, 288
Injections, antiseptic, 176, 180, 190, 191, 208, 218, 238, 255, 258, 269, 329, 390, 392, 419
Insect bites, 388
Insects, carriage of disease by, 350, 358

Insecticides, 16, 38, 138, 139, 146, 159, 176, 177, 200, 208, 228, 237, 239, 245, 255, 278, 285, 294, 327, 329, 382
Instruments, sterilizing, 101, 150, 234, 262, 270, 318, 319, 386, 387, 391
Internal antisepsis and disinfection, 109, 135, 137, 405 (*see also* Disinfection internal)
Invicta sprayer, 344
Iodantipyrin and Iodpyrin, 252
Iodates, 101
Iodic hydrargyrum, 188
Iodide of ethyl, 104
,, ,, mercury, 187, 387, 399, 400
Iodine, 100, 374, 388, 390, 395, 398
,, cyanide, 102
,, trichloride, 101, 374, 384
Iodocresol, 210
Iodocrol, 281
Iodoform, 103, 390
Iodoformin and Iodethylformin, 320
Iodol, 105, 252, 388
Iodophenols, 210
Iron and its salts, 160, 448
,, sulphide produced by bacterial action, 161
Itrol, 193
Izal, 220, 227-231, 338, 447

J

Jams, keeping, 273, 414
Jeyes' creolin, 222
,, Fluid, 220, 221

K

Kerite, 116
Key's screen, 358
Kieselguhr, 18, 207, 318
Kocide, 326
Kreosote and Kreolin (*see* Creosote *and* Creolin)
Kyanizing, 382

L

Lactacidine, 273
Lamps, fumigating, 100, 235, 284, 305, 308
Lanoform, 405
Lanolin, 328, 395, 405
Laplace's solution, 183, 185
Lard bleachers, 273
Largin, 194
Larymore boiler, 359
Lauraline, 200
Lavallées' solution, 392
Lawes' Fluid and Powder, 224
Lawrence water sterilizer, 361
Lead and its compounds, 178, 291, 388, 412
Leather goods, disinfecting, 38, 298, 304, 311
Ledoyen's liquid, 178
Legal statutes and regulations, 436
Leucoline (*see* Quinoline)
Light, action of, 10-14, 341
Lime, 148, 149, 338, 370, 397, 412, 448, 450
Lingner's formaldehyde apparatus, 315
Liquor carbonis detergens, 391
,, sodæ chlorinatæ, 85
Listerine, 142
Little's soluble Phenyle, 239
Loretin, 257
Luder and Seidloff's disinfecting powder, 165
Lupus, 210
Lysol, 217, 225, 384, 395, 397
Lysolveol, 219

M

Mackenzie spray, 344
McDougall's disinfecting powder, 205
McLautlin's steam disinfector, 73
Magdeburg preservative salt, 143
Magnesium biborate, 141
,, bisulphite, 135
Magnetic carbide, 162
,, oxide of iron, 161, 162
Maiche's water sterilizer, 362
Malaria, 358
Malic acid, 141, 329, 330
Manganates, 168, 364
Manganese and its compounds, 166, 364
Manganous carbon, 167
Mayer's steam disinfector, 72
Mayor's disinfecting powder, 206
Meat, preservation of, 13, 29, 140, 141, 143, 163, 207, 216, 236, 246, 250, 261, 264, 296, 408, 415, 418
Mechanical disinfection, Chap. II.
,, filters, 20
Meditrina solution, 92
Meillère's disinfectant, 155
Menthene, 279
Menthol, 282
Mentho-phenol, 283
Mercuric Bactericide, 291
,, chloride, 140, 261, 335, 336, 346, 385, 388, 444, 447, 483
Mercury and its compounds, 178, 195, 196, 204, 211, 249, 291, 322, 329, 392, 399
Metallic contamination of food, 411, 412
Metals, disinfecting action of, 143, 160, 166
Methylamines, 247
Methylene blue, 251
,, dichloride, 294
Methyl alcohol and Methyl chloride, 234, 294, 321
,, violet, 250, 384
Microsol, 160
Middle ages, attempts at disinfection in the, 4

Milk cans, 335, 429
,, condensed, 432
,, danger of infected, 415
Milk inspection, 440
,, preservation, 134, 143, 145, 148, 176, 195, 232, 250, 266, 273, 274, 422, 429
,, souring of, 421, 429
Mineral waters, 144, 406
Mixtures often more powerful than simple ingredients, 216
Molecular proportions, 421
Morel-Lavallées' solution, 392
Mosaic Law, 3
Moth, preventing, 240
Moulds, 145, 148, 150, 151, 314, 329, 348, 383, 413
Mouth washes, 404
Mucor, 250 (*see also* Fungi)
Musk, 278
Mustard, essential oil of, 328
Mycoderma aceti, 140, 325, 411
Myrrh, 410
Myrtol, 286

N

Naphthalene and its derivatives, 199, 239, 253, 350
Naphthols, 240, 481
Naphtholsulphonates, 242
Nargol, 194
Necrosis, 280
Nicotine, 253, 255
Nitre or Nitrate of potash, 148, 409, 419, 421
Nitric acid and nitrogen oxides, 122, 197
Nitrobenzene, 244, 287
Nitrocellulose, 246
Nitro-compounds, 122
Nitroglycerine, 246
Nitrohydrochloric acid, 378, 379
Nitrophenols, 244
Nitrous ether, 124
Nobro sprayer, 344

O

Odamine, 224
Odours, insufficiency of removing or masking, 3, 9
Oil of Wintergreen and sweet birch, 269
,, use of for preserving, 411
Oils, essential, 117, 121, 142, 283, 289, 390
,, solutions in, 202, 208, 329
,, sterilizing, 396
Ointments, 126, 243, 178, 190, 210, 234, 240, 243, 251, 267, 281, 286, 329, 392, 404
Okol, 231
Oleates, 398
Oleic acid, 328
Oleocreosote, 237
Ophthalmia, 188, 189, 251, 262
Orphol, 192
Osmic acid, 194, 387
Oxalic acid, 330
Oxidases, 365
Oxygen, 110, 363, 364
,, inhalation of, 144, 145
,, for preserving food, 145
Oxynaphthoic acid, 243
Oxyphenols, 215
Oxyquinoline, 257
Ozæna, 278
Ozone, 112, 122, 227, 287, 288, 364

P

Pail system of disposing of excreta, 349
Paper, antiseptic, 34
Paraformaldehyde, or "paraform," 308
Parasites, killing, 16, 38, 146, 159, 176, 178, 179, 190, 208, 212, 228, 236, 240, 242, 258, 267, 345, 397, 416 (*see also special headings*)
Paris, disinfection in, 183
Paris green, 177
Pasteur-Chamberland filter, 20, 363
Pasteurization, 430
Pasteur's investigations, 5
Pearson's antiseptic, 224
Peat, 16, 17, 209, 236, 288, 348, 364
Pemmican, 408
Peppermint, 282
Perchlorates, 95
Perchloride of mercury, 179
Perfumes, 3, 278, 287, 288, 330, 402
Periodates, 102
Permanganates, 115, 169-172, 197, 331, 335, 338, 347, 351, 364, 381, 405, 474
Peronospora infestans, 159
Peroxols, 293
Peroxide of hydrogen, 118, 293, 346, 405, 418, 429, 474
,, ,, barium, 120
,, ,, sodium, 120
,, ,, manganese, 166, 167
Peroxides, general properties of, 120
Persulphates, 137, 197
Peru, Balsam of, 264
Petroleum, 200, 329
Phenanthrene, 212
Phenegol, 211
Phenol, 197, 200, 318, 322, 331, 336, 337, 342, 388, 395, 401, 450, 475
,, in sheep dips, 177
Phenolith, 206
Phenoloids, 209, 214, 476
Phenosalyl, 270
Phenolsulphonates, 156, 190, 211, 388, 407
Phenyl-substituted fatty acids, 213, 277, 388
Phenylacetamide, 250
Phenylamine (*see* Aniline)

Phosphates, acid, 136
Phosphoric acid, 419
Phthisis, 100, 104, 140, 144, 216, 238, 276, 283, 329, 392 (*also see* Tuberculosis)
Phylloxera, 138, 139
Picric acid, 244
Pig-styes (*see* Stables)
" Pinking " of water, 364
Pinol, 293
Pitch, 235
Pixol and Pixene, 219
Plague, 3, 89, 278, 282, 325, 331, 346, 354
Plants, applications for, 16, 133, 139, 146, 159, 160, 200, 237, 295, 329 (*also see* Parasites and Spraying Apparatus)
Pneumatic treatment of diseases, 144
Potash or Soft Soap, 394
Potash salts, 147
Potassium permanganate, 169, 261
Potato blight, 159, 160
Poudre de Corne et Desneaux, 18
Powders, disinfecting, 18, 201, 205, 207, 288, 332, 350, 478
Preservation of food, 2, 121, 134, 139, 145, 295, Chap. XIV., p. 408
,, ,, animal and vegetable specimens, 108, 141, 241, 245, 266, 318, 321
Preservatives Committee, report of, 423
,, effect on health, 109, 119, 134, 271, 273, 281, 284, 327, 414, 417, 422
,, regulations as to, 424 (*see also* Boric and Salicylic acids)
Pringle's researches, 4, 98
Privies, disinfection of, 164
Propionic acid, 213, 326
Protargol, 193
Protococcus, 147
Ptomaines, 9, 144, 157, 415
Public disinfection, 331
Public installations, 74
Pyoctanins, 250, 251
Pyridine, 200, 227, 252, 253, 254
Pyrogallol or pyrogallic acid, 233
Pyroligneous acid, 234, 236, 326, 341
Pyrolusite, 166, 167
Pyroxanthin, 235
Pyrrol, 252

Q

Quarantine, 7, 304
Quibell's disinfectant, 225
Quickline, 148
Quinaphthol, 242
Quinine, 262, 263, 265, 407
Quinol, 233
Quinoline, 200, 253, 256
Quinosol (*see* Chinosol)

R

Rademann's patent, 209
Radium rays, 14
Radlauer's Antisepsin, 155
Rags, 355
Railway carriages, 183, 354
Ransom's disinfector, 36
Rats, 354
Reck's disinfector, 66
Reducing disinfectants, 127, 131, 163
Refrigerating chambers, 425
Refuse, disinfection and disposal, 333
Resaldol, 276
Resole, 220, 235, 242
Resopyrin, 252
Resorcinol or Resorcin, 232, 233, 328, 388, 407, 481
Retinole, 235
Ringworm, 242, 319
Road disinfection, 207
Roberge's formaldehyde generator, 313
Rohrbeck's steam disinfector, 72
Röntgen rays, 14
Rooms, disinfecting, 77, 84, 96, 100, 122, 129, 132, 160, 183, 247, 248, 334, 335, 345, 445
Rotterine, 156
Roylat disinfector, 171

S

Saccharin, 267
Safranine, 251
St. Bede disinfectant, 185
Salbromanilide, 270
Salicylic acid, 143, 146, 156, 267-276, 334, 388, 399, 420, 480
Salipyrin, 252, 270
Salivation through mercuric chloride, 183, 185
Salol, 269
Salophen, 269
Salt, common, 97, 409, 450
Salting, 416, 417
" Salting " of coal tar disinfectants, 214
Saltpetre, 148, 409, 417
Salubrine, 324
Salufer, 105, 398
Sand filtration, 18-20
Sanitas, 121, 122, 288, 290-293, 391, 404
Sanitas Formaldehyde Fumigator, 318
Sanoscent, 284
Sapo-kalinus " mollis " or " viridis," 394
Saprol, 225
Savonal, 394
Scabies, 199, 243
Schimmel's steam disinfector, 69
Schmutz-decke, 19
Scoradine, 283
Seeds, treatment of, 125, 159, 176, 204, 244, 497
Sergeant's Incinerator, 75

Sewage, chemical treatment of, 88-93, 113, 136, 149, 150, 152, 155, 157, 158, 162, 163, 166, 167, 168, 172, 173, 176, 223, 234, 247, 337
Sewers and drains, 331
Sharratt's Formaldehyde "Regenerator," 318
Sheep-dips, 176, 228
Ships, disinfection of, 129, 180, 183, 439
Shpreotz Sprayer, 318
Sick rooms, 445
Siemens' ozonizer, 114
Silicate of soda, 412
Silicofluorides, 105
Silk, sterilizing, in surgery, 387
Silver compounds, 193-194, 323
Sinks, 335
Skin, disinfection of the, 387
Skins, infection by, 355
Slaughter-houses, 353
Smoked provisions, 408, 410, 415
Soap, antibacterial action of, 148, 150, 208, 262
Soaps, medicated, 188, 269, 284, 287, 392, 480
Soda chlorinata, 85, 390 (*also see* Hypochlorites, 404)
,, solutions, disinfectant power of, 393
Sodium chloride, 97, 416
,, chloro-borosum, 143
,, peroxide, 120, 358, 369
,, salts, 97, 134, 137, 147, 150, 339
Softening of water, 21, 369
Soils, survival of organisms in, 26, 27
Solutol, 219, 225
Solveol, 220, 225
Soot, 16
Sozal, 212, 391
Sozo-iodol, 105, 211
Spiegeleisen, 166
Sponges, 387
Spongy iron, 161, 162
Spores of organisms, 2, 31, 52, 145, 148, 149, 152, 181, 191, 203, 222, 225, 228, 229, 237, 244, 282, 317, 327, 341, 363, 393
Spraying of rooms, 159, 183, 222, 300, 343, 346
,, of body cavities, 389
Sprays for plants, 160, 177
Sputa, disinfecting, 68, 210, 218, 336, 341 (*also see* Tuberculosis)
Stables, disinfection of, 97, 99, 353
Standardization of disinfectants, 393, 457-471
Stannous chloride, 191
Staphylococcus pyogenes aureus, 91, 94
Steam disinfectors, 36, 44, 47, 57 59, 62, 66, 69, 71, 72, 73, 74, 384
,, disinfection, 339, Chap. III.
,, experiments on the penetrating power, 43, 50, 52
Steam, varying conditions of, 32, 38, 39
Sterilization, meaning of, 1
,, by heat, Chap. III., 429
,, by chemicals (*see under the various agents*
,, of Water by Heat, 359
,, ,, by chemicals, 363
,, ,, by acids, 374
Sterilizing filters, 20
Storax balsam, 276, 277
Stoves, disinfecting, 33
Streets, 350
Streets, disinfection of, 207
Strock's antiseptic paper, 143, 275
Styracin, Styracol and Styrone, 276, 388
Sublamin, 249
Sublimate, corrosive (mercuric chloride), 140, 179
Subtilis, Bacillus, 184, 223, 229, 233, 313, 322
Succinic acid, 330
Sugar as a preservative, 411, 416
Sulphate of lime, 18, 148
Sulphates, 137 (*see also under respective bases*)
Sulphide of iron produced by bacterial action, 161, 163
Sulphites and bisulphites, 131, 134, 406, 473
Sulphobenzoic acids, 267
Sulphocarbolates (*see* Phenolsulphonates)
Sulphocarbonates, 138
Sulpholeate of sodium, 405
Sulphonic derivatives, 210-212, 240, 257, 420
Sulphur and its compounds, 3, 76, 125, 354, 348, 409
Sulphur candles, 130, 310
Sulphur dioxide and sulphurous acid, 127, 304, 342, 356, 390, 419, 424, 425, 444, 473
Sulphuretted hydrogen, 126, 406, 411
Sulphuric acid, 136, 406
Superheated steam, 38
Suvern mixture, 149
Syphilis, 178, 228
Syphons of liquefied SO_2, 128

T

Tannin and tannic acid, 163, 277, 410
Tanning, arsenious sulphide in, 177
Tar and its products, 198, 476
,, from wood, 234, 388
Tartaric acid, 329, 378
Terebene, 284, 404
Terpenes, 278, 280
Terpineol, 286
Terpin hydrate, 286
Thalline, 258
Thiocamf, 131
Thiophene, 199

Thiosulphates, 136, 143, 190
Thorncliffe disinfectant, 228
Thresh disinfector, 57
Thursfield's disinfectors, 59, 316
Thymocresol, 281
Thymol, 278, 280, 293, 391, 402, 407, 481
Thymol-mercury compounds, 191
Timber, preservation of, 153, 246, 381
Tinned foods, 412
Tin salts, 191, 291, 412
Tobacco, 254
Tolu, Balsam of, 264
Toluene, 199
Toluidine blue, 251
Tooth powders, 209, 269, 404
Towns, disinfection in, 330
Traumatol, 210
Tribromophenol, 210, 476
Trichlorphenol, 210
Tricresol, 216
Triformol, 319
Trillat's Autoclave (formaldehyde), 301
Trimethylamine, 247, 248
Trinitrophenol, 244
Trioxymethylene, 294, 308, 313
Tuberculosis, 68, 69, 140, 149, 154, 184, 191, 194, 203, 210, 229, 236, 238, 249, 250, 267, 270, 281, 286, 312, 313, 336, 341, 345, 350, 390
Turpentines, 121, 278, 280, 409
Tuson's disinfectant, 155
Typhoid and B. typhosus, 12, 27, 87, 94, 101, 119, 121, 123, 145, 151, 158, 172, 182, 190, 203, 211, 216, 218, 224, 225, 228, 232, 233, 240, 241, 251, 261, 292, 297, 309, 314, 324, 329, 338, 339, 350, 363, 364, 368, 370, 372, 380, 396, 442
Tyrosine, 256
Tyrotoxicon, 415

U

Unguentum hydrargyri, 178
,, hydrarg. nitratis, 179
United States, disinfection practice in, 76, 179, 180, 182
Urinal cakes, 155, 171, 199, 284, 285
Urinals, 352
Urine, sterilizing, 248, 265, 267, 268, 270, 271
Urotropine, 248, 407
Uterine injections, 219

V

Vaccination, 407
Vaccine lymph, 80, 281, 292
Vacuum apparatus, 41, 42, 47
Vaillard-Desmaroux water sterilizer, 359
Valerianic acid and Valerol, 283, 326
Vanillin, 287
Vaseline, 395, 404
Vegetable acids, 329
Vehicles, 354
Verbena, oil of, 283
Verdigris, 159
Vermin (*see* Parasites)
Vienna mixture, 407
Vinegar, 134, 140, 324, 390, 410, 436
Vines, 138, 139
Violets, methyl and gentian, 250
Vitos, 224

W

Wade's cistern disinfector, 171, 347
Walls and wall papers, 156, 334
Washing powders, disinfectant, 287
,, soda, 148, 150
Washington Lyon's disinfector, 44, 47
Water purification, 18-23, 146, 157, 160, 161, 173, 359
,, closets, 347
,, carts, disinfectants in, 350, 351
Webster's electrolytic process for water, 161
Wheat, 435
Whey, carbonated, 146
White precipitate, 190
Wines, preservation of, 134, 140, 272, 324, 327, 409, 419
Wintergreen oil, 269
Wood creosote, 235
,, paving (*see* Streets)
,, preservation of, 381
,, spirit, 234, 294, 415
,, tar and its products, 234, 378, 388, 410
,, wool, 390
,, work, disinfecting, 335
Wool, infected, 355
,, medicated, 208, 482
Woolf process, 92
Worms, intestinal, 239, 381
Wounds, applications for, 193, 194, 199, 218, 233, 234, 239, 250, 257, 266, 277, 281, 319, 320, 323, 347, 364, 387, 391, 405

X

Xanthates, 138
Xeroform, 210
Xylenol, 214, 215

Y

Yards, 351
Yarnold ozonizer, 114
Yeast, 107, 150, 177, 181, 204, 246, 258, 297

Z

Zinc and its salts, 143, 151, 291, 329, 338, 345, 382, 388, 391, 399, 404, 420
Zinc-mercury cyanide, 189
Zinc paraphenolsulphonate, 211

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